APPENDIX D

SEWER SYSTEM EVALUATION STUDY

FINAL REPORT AND COST ANALYSIS

City of Lawton

Sewer System Evaluation Study Report Volume I

for Wastewater Collection System Improvements

Biggs and Mathews
BYRD Forbes
CH2M HILL

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VOLUME ONE

EXECUTIVE SUMMARY

1.0 Introduction

In September, 1994 the City of Lawton, Oklahoma was placed under an Environmental Protection Agency ("EPA") Administrative Order for non-compliance with their NPDES permit relative to unauthorized overflows from the sewer collection system.

Then in May, 1995 the Oklahoma Department of Environmental Quality ("ODEQ") and the City executed a Consent Order Agreement to perform a Sanitary Sewer Evaluation Study ("SSES").

In compliance with the Administrative Order and the Consent Order, an SSES was performed to identify necessary collection system repairs and required expansion/improvements to reduce sewage overflows as a result of inflow, infiltration, and/or lack of capacity.

The scope of work included in the study generally consisted of flow monitoring, physical inspection, smoke testing, internal T.V. inspection, system modeling, and rehabilitation/expansion recommendations with cost estimates.

2.0 Collection System Evaluation and Results

Thirty-seven (37) temporary flow meters were installed throughout the three major drainage basins to document wet and dry weather flows. From the flow metering data, it was determined that wet weather does impact the system. In the Cache Creek basin over 80% of the inflow occurs on less than 40% of the basin area. In the Squaw Creek basin, 80% of the inflow occurs on 70% of the basin area, and in the Wolf Creek basin, 80% of the inflow occurs on 60% of the basin area.

The collection system consists of approximately 6094 sewer manholes and 392 miles of sewer line ranging in size from 6" to 60" in diameter.

Smoke testing was performed on 1,614,000 linear feet of the system with defects observed in manholes, mainline segments, and private service lines. The various line segments were selected for smoke testing based on the results of the flow monitoring.

Subsequently, from the physical inspection and smoke testing, inspection of line segments by Closed Circuit Television (CCTV) was recommended for approximately 111,000 linear feet of sewer. Many of the concrete lines showed severe deterioration due to hydrogen sulfide corrosion and some of the lines had partially collapsed.

3.0 System Modeling and Hydraulic Analysis

A computer model was developed consisting of 1,476 line segments (manhole to manhole) of 10" and larger diameter pipe for a total of approximately 493,000 linear feet.

The model showed that during dry weather conditions, the existing system has adequate capacity to convey the wastewater to the treatment plant without overflows.

However, during the ODEQ approved design storm (2-Year/24-Hour Rain Event & 2020 Population Plan) the existing collection system cannot convey wastewater and wet weather inflow to the treatment plant without numerous widespread system overflows.

4.0 System Rehabilitation Recommendations

In an attempt to reduce wet weather inflow by 25% to 30%, and to enhance the long-term structural integrity of the existing system, an extensive rehabilitation and repair program is recommended to specifically address public collection system mainlines, collection system manholes, and private service lines.

Within the three major drainage basins, rehabilitation is recommended for 1625 manholes, 191,000 linear feet of mainline, and 2,109 private service lines.

In addition it is recommended that the City of Lawton establish and maintain an aggressive preventative sewer maintenance program so that every line in the system is cleaned/T.V. inspected on a 5 year cycle.

5.0 System Expansion Recommendations

Numerous expansion/upgrade projects are recommended to increase the system capacity in selected areas.

In order to convey the post-rehabilitation flows and to accommodate the increased flows based on the growth projected in the City's 2020 population plan, it will be necessary to install approximately 92,500 linear feet of new line ranging from 10" to 42" in diameter.

6.0 Final Report Closure

Based on the results of the study report, the following observation and conclusions are offered:

- Dry weather capacity problems do exist; however, with the exception of periodic line stop-ups, dry weather flows are conveyed to the treatment plant without overflows.
- Wet weather inflow entering defective portions of the collection system does impact the system and causes sanitary sewer overflows.
- The City should initiate, as outlined in this study report, an aggressive and comprehensive rehabilitation/repair program in an attempt to reduce the wet weather inflow by 25% to 30%.
- Sanitary sewer overflows cannot be contained during the design storm by system rehabilitation/ repair work alone.
- The City should provide for selected area expansion/upgrade of lines, as outlined in this study report, to adequately convey the ODEQ approved Design Storm (2 Year/24-Hour & 2020 Plan).
- All recommended collection system rehabilitation/repair work should be completed throughout the system by December, 2014.
- Flow monitoring should be conducted periodically throughout the rehabilitation/repair program to assess and document the inflow reduction results.
- Along with the collection system rehabilitation/repair program, the recommended system expansion/upgrade lines should be constructed.
- All recommended collection system expansion/upgrade lines should be completed and in operation by December, 2018.
- The City should begin by May 1, 1997 their preventative sewer maintenance program so that the complete system is cleaned at least every 5 years.
- As funds become available the City should address the high maintenance line segments listed in Appendix "E". Consideration should be given to replacement of these lines.

7.0 Cost Estimates and Schedule

A comprehensive rehabilitation and expansion program is recommended for the City of Lawton.

The estimated costs for the proposed rehabilitation and expansion program is $61,250,000, and is shown in table form on the following page.

The majority of rehabilitation work to repair the collection system defects for the reduction of wet weather inflow is scheduled for completion within the first 12-years, with the remaining inflow reduction work completed by the year 2014.

The expansion/upgrade projects will be done in conjunction with the rehabilitation program with all work being completed by the year 2018.

SYSTEM REHABILITATION/EXPANSION COST SUMMARY

Item	Quantity	Estimated Cost
Manhole Rehabilitation	1,625 EA	$ 698,000
Mainline Rehabilitation	191,000 LF	18,986,000
System Expansion/Upgrade	92,500 LF	20,700,000
Wet Weather Facility	15MG 1-EA	2,250,000
	Sub-Total (Construction)	$ 42,634,000
Engineering and Inspection	LS	4,466,000
Contingencies	LS	5,460,000
	Sub-Total (Engineering and Contingencies)	$ 9,926,000
City Maintenance Identified Rehabilitation	LS	7,500,000
Administration of Private Service Rehabilitation	LS	680,000
Flow Monitoring Assessment	LS	510,000
	Estimated Grand Total	**$ 61,250,000**

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FINAL REPORT

SANITARY SEWER EVALUATION STUDY

1.0 Introduction

The City of Lawton, Oklahoma ("City") owns and operates a wastewater plant, which, treats an average dry weather flow of approximately 10,000,000 gallons per day ("GPD").

During storm events in which area rainfall amounts range from 2" to 3.7" in a 24-hour period (1 year to 2 year - 24-hour event), it is not uncommon for the treatment plant to receive an additional 28,000,000 gallons of extraneous water. With such wet weather flows, the collection system rapidly becomes overloaded and overflows occur in various portions of the system.

1.1 Administrative Order and Consent Order Compliance

In September, 1994 the City of Lawton was placed under an Environmental Protection Agency ("EPA") Administrative Order for non-compliance with their NPDES permit relative to unauthorized overflows from the sewer collection system.

Then in May, 1995 the Oklahoma Department of Environmental Quality ("ODEQ") and the City executed a consent order agreement to perform a Sanitary Sewer Evaluation Study ("SSES").

In an effort to comply with the EPA Administrative Order and the ODEQ Consent Order, the City contracted with CH2M-Hill to provide the necessary professional services for a system-wide SSES.

1.2 Purpose of Study

The purpose of the study was to comply with the EPA Administrative Order by identifying necessary collection system repairs and required system expansion/improvements to reduce sewage overflows as a result of inflow, infiltration, lack of capacity, or other design and/or construction related deficiencies.

In addition to providing for a full evaluation of the collection system, the comprehensive study was designed to develop a rehabilitation/capital improvements program including a prioritized listing of recommended improvements and their associated costs.

1.3 Scope of Work

The scope of work for the study consisted of 10 major work tasks which were specifically designed to provide for a complete evaluation and analysis of the collection system.

Outlined below is a summary of the various tasks within the scope of work and as amended throughout the project.

Task No. 1 - Mobilization/Project Administration

- Conduct organiztional meetings with City Staff and provide for an overall SSES project briefing.
- Establish filing systems for field data.
- Establish monthly project meetings to maintain schedule and budgets.
- Develop/implement a Quality Assurance/Quality Control Program.
- Schedule field personnel, mobilize project team, and set up local office.

Task No. 2 - System Mapping/Surveying

- Gather historical information for wastewater collection system.
- Develop a manhole and line segment numbering system for identification and inventory purposes.
- Provide collection system inventory of public sewers and manholes.
- Perform field survey of system manholes on lines 10-inches and larger with rim/cover elevations and coordinates.
- Create an "updated" sewer collection system map (scale: 1" = 200') in AutoCad format.
- Provide digital photography covering approximately 60 square miles of the City at a scale of 1" = 200'.
- All data and map files shall be compatible and set-up in a AutoCad release 12 or later version.

Task No. 3 - System-wide Flow Metering and Data Analysis

- Establish subbasin boundaries for metering.
- Determine and investigate flow meter sites.

- Clean flow metering sites for preparation of meter installation.
- Installation of thirty-seven (37) temporary flow meters to measure dry and wet weather flows.
- Provide for 6 rainfall gauges to record various storm intensities and durations.
- Provide for maintence, operation, and data collection from all meters and rain gauges.
- Determine average flow under dry weather conditions for each site.
- Provide for analysis and tabulation of rainfall data and plots on flow hydrographs for each rainfall gauge and flow meter site.
- Determine peak inflow/infiltration rates under wet weather conditions at each flow monitor site.
- Determine relationship between peak inflow and rainfall intensity (Q vs. I) at each flow monitor site.
- Determine in-situ capacity of the existing pipeline segments for the portion of the system being metered.
- Identify peak rainfall induced inflow/infiltration from flow metering data.
- Compile and summarize all field data and evaluate and prioritize subbasins for smoke testing.
- Provide for meter removal.

Task No. 4 - Manhole and Line Segments Physical Inspection

- Provide above ground visual inspection at all manholes and along all line segments within the collection system.
- Document physical condition of the manhole exposed exterior, manhole lid, and other conditions along the line segments which could potentially indicate a system defect or inflow source.
- Provide rim to invert measurements on all manholes on lines 10 inches and larger.
- Record on computer forms all manhole and line data and incorporate into data base.

Task No. 5 - Collection System Smoke Testing

- Provide for "Notice To Residents" in smoke testing areas.
- Coordinate with City's fire and police departments relating to smoke test areas.
- Identify/Document exact locations of each system defect or source of infiltration/inflow, and include in the data base.
- Quantify each inflow source by considering the surrounding area

and the amount/density of the smoke encountered.

Task No. 6 - Internal Television Inspection

- Develop and Compile a television justification report based on the smoke testing, and dye flood tests.
- Prioritize line segments recommended for internal inspections.
- Clean utilizing a combination pressure/vacuum system in order to facilitate television inspection.
- Provide for internal inspection by television camera to determine structural conditions, method of rehabilitation, verify location of cross-connections or defects, and verify pipe joint conditions.
- Display information to be documented on videotape that indicates the line segment being televised, date televised, the line size, and distance from the entry manhole.
- Data to be recorded on a television log and all field notes, photographs, and videotapes provided on the selected line segments.

Task No. 7 - Analyze and Evaluate Collection System

- Input the existing flowline elevations, pipe sizes, line segment lengths, and top of manhole elevations (MSL) by conventional surveying methods for all interceptors/mains to be included in the model. (Lines 10 inches and larger)
- Investigate/collect the necessary information with regards to future development pending for calculation of estimated future sewage flows.
- Develop a computer model utilizing HydroWorks Software for analysis of the system.
- Provide for a maintenance inventory system, Maintenance Management System (MMS) by Applied Geographic Technologies.
- Define and construct the model from field survey data and existing system maps by imputing pipe diameter, pipe lengths, pipe invert elevations, top of manhole elevations, pipe roughness coefficients, and the 2-Year design storm event.
- Develop diurnal flow curves representing average daily flow from actual dry weather flow metering data for input into the computer model at meter locations in order to calibrate the system under normal flow conditions.
- Develop an infiltration/inflow hydrograph (based on "flow metering results") at each metering site for input into the model.
- By computer analysis, determine the theoretical hydraulic capacity of the existing system, and determine the hydraulic grade line for

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the system under normal conditions.

- Determine and analyze the effect of the design storm event imposed on the system.
- Provide system schematic and detailed cost estimates for recommended improvements.

Task No. 8 - Final Report and Recommendations

- Final comprehensive report will provide a summary of field activities and final results.
- A priority ranking of each system defect will be documented, with public and private sector defects indentified separately.
- Recommendations for system rehabilitation/expansion to be provided along with budgetary cost estimates.
- Summary of the supporting data to be provided for recommended improvements.
- The hydraulic model, database, updated maps, videotapes, and field documentation and photographs to be presented in the final report.
- Provide six copies of an Executive Summary and Final SSES Report, along with three sets of supporting appendices.

Task No. 9 - SSES Deliverables

- Comprehensive flow metering results.
- Ranking for each defect by priority.
- Private and Public sector defect designation.
- Executive summary report.
- Final Report - Rehabilitation plan and cost estimates.
- Appendices - sketches, field logs, photographs, field database, photos.
- Assistance to City of EPA Quarterly Reports.
- Presentation of final report to City, State, and EPA.
- Updated collection system maps in ArcCad.
- MMS Software & Database.
- Calibrated Hydraulic Model & HydroWorks Software.
- Five flow meters, data logger, flow meter software, and accessories.
- Three rain gauges and rainfall software.
- Two smoke machines.
- Computer Hardware and Software.
- Training for Model, MMS, rain gauges, smoke machines, and flow meters.

Task No. 10 - Hardware/Software Support

- Identify computer hardware/software for City to Utilize Hydro Works, MMS, and other applications.
- Provide other digital photography. (1" = 200')
- Provide digitized map files to show structures as planinmetric features.
- Provide digitized map files showing streets as planinmetric features.
- Digitize lot/block boundaries.
- Provide contour elevations.

2.0 Collection System Evaluation and Results

A sanitary sewer condition assessment was conducted on the City of Lawton wastewater collection system to establish existing hydraulic flows at key locations and determine the condition of the sewer system serving the City. System defects were identified and documented to establish repair estimates. The assessment included temporary flow monitoring, manhole inspections, smoke testing, and internal closed circuit television inspection.

The Lawton wastewater collection system consist of approximately 392 miles of pipes (as of 9/1/96) ranging in sizes from 6 to 60 inches. Figure 2.1 presents a summary of the pipeline inventory by pipe size.

2.1 Flow Monitoring

There are various reasons to monitor wastewater flows. This project concentrated on establishing dry and wet weather hydraulic conditions in order to identify the magnitude of infiltration/inflow, establish pipeline capacity, and provide flow data for the hydraulic model calibration. Flow data presented in this report represents flows within the collection system in its present state. It should be emphasized, however, that collection systems are very dynamic in that new lines are constantly being added or repairs being made that may change the flow rates or characteristics recorded during this study. The emphasis on this project was in the area of pipeline capacity analysis with the specific purpose of producing a data set for use in hydraulic modeling of the collection system. The methodology and equipment used to implement wastewater monitoring may vary depending on the application. For this project, American Sigma area velocity meters were utilized to obtain representative flow data under the various hydraulic conditions anticipated.

Each meter was field calibrated prior to installation. Calibration is a simple procedure consisting of the verification of the depth and velocity measurements of the flow

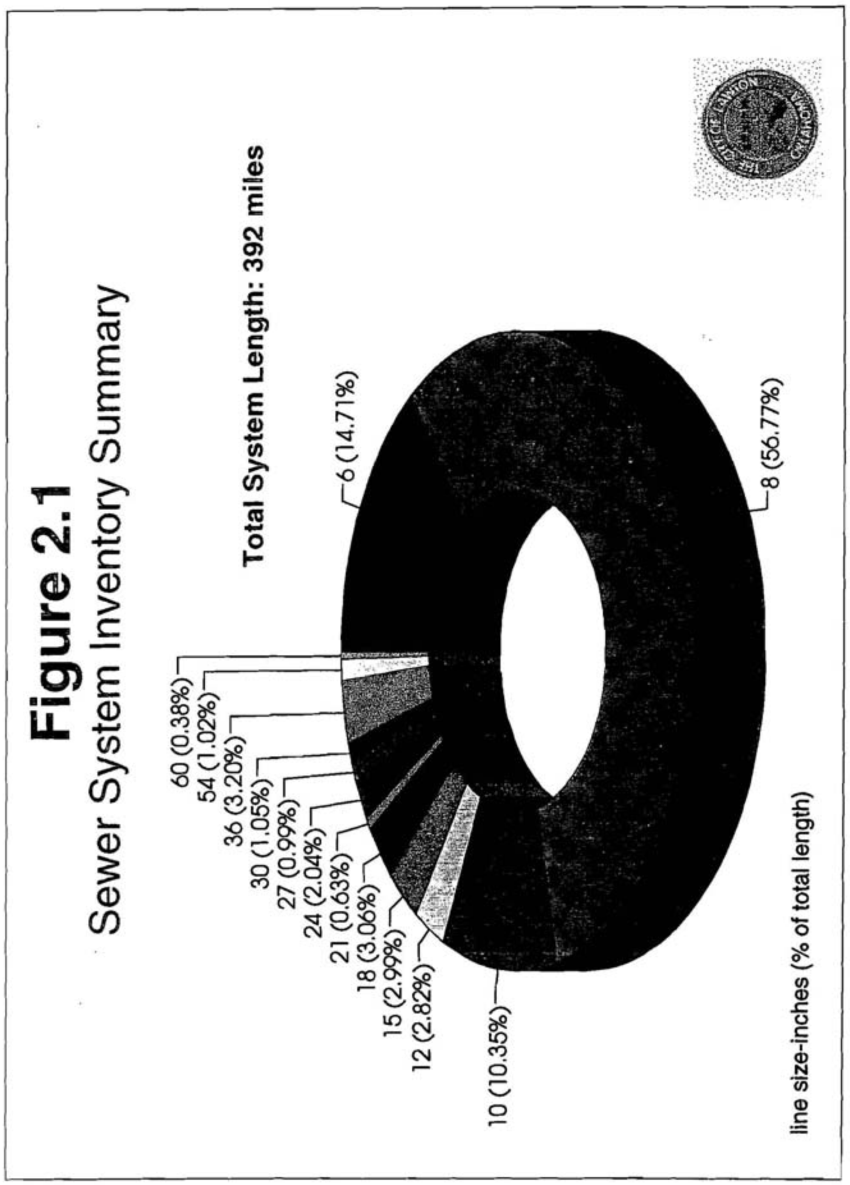


Figure 2.1
Sewer System Inventory Summary
Total System Length: 392 miles
60 (0.38%)
54 (1.02%)
36 (3.20%)
30 (1.05%)
27 (0.99%)
24 (2.04%)
21 (0.63%)
18 (3.06%)
15 (2.99%)
12 (2.82%)
10 (10.35%)
6 (14.71%)
8 (56.77%)
line size-inches (% of total length)

meter versus physical measurements. Installation consists of mounting the sensors on a steel mounting band that fits snugly in the pipeline. The data logger is then installed and secured in the manhole and the meter is activated at user defined sampling intervals.

Routine maintenance and service were undertaken during the flow monitoring period to confirm normal operation. The ability of the flow meter to record flow data is not affected by changing flow conditions such as surcharge or backwater conditions. However, physical obstructions such as debris and sediment do affect depth and velocity measurements adversely.

Originally, thirty-eight flow meters were installed which effectively segregated the system into thrity-eight sub-basins. However one meter (meter 301) had to be removed due to a continuous buildup of grease which rendered the meter inoperative.

Initial analysis of the flow data was performed by reading the raw data from the meter memory. This data was then uploaded to a personal computer for processing. A tabular and graphical presentation of the data was developed that provided specific information for the detailed evaluation.

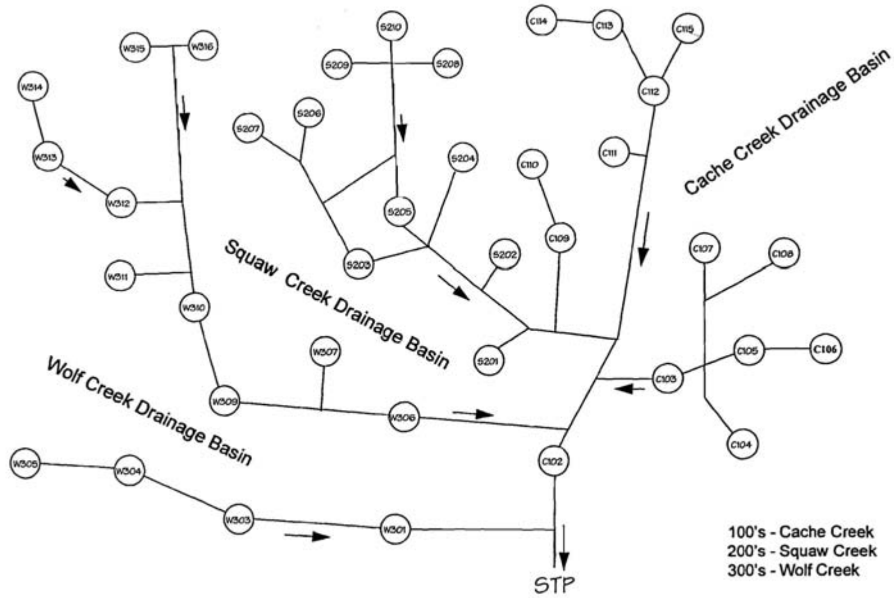
The data from thirty-seven flow meters was gathered for a period of approximately 45 days spanning May and June 1995. The metered sub-basins were then grouped into three larger drainage basins: Cache Creek, Squaw Creek, and Wolf Creek. A flow schematic of the collection system is presented in Figure 2.2 to indicate the flow pattern for the entire collection system and the boundary designations for the three major basins. The flow meter and also rain gauge locations are shown on a map presented in Figure-1 Appendix "A". The length of the monitoring period for each site varied from a minimum of 45 days to a maximum of about 60 days. Weekly site visits were conducted to retrieve the recorded raw data and to document field conditions.

2.2 Flow Data Analysis

Flow data was analyzed on a site by site basis for the entire monitoring period. Analysis of each site was performed by comparing the flow calculated by the continuity equation ($Q = VA$, where Q is flow, V is average velocity and A is the cross-sectional flow area) with flow calculated by the open channel Manning flow equation ($Q = 1.49/n\ R^{2/3}\ S^{1/2}\ A$, where n is Manning's coefficient, R is hydraulic radius, and S is slope).

For all sites the raw flow data was collected on 15 minute intervals. Hourly wastewater flow data and daily hydraulic summaries averaged from the 15 minute data for each of the thirty-seven monitoring sites are tabulated and presented in the flow monitoring data (Volume Two).

Figure 2.2
Wastewater Flow Schematic Diagram



Rain data from six rain gauges was also collected on 15 minute intervals during the monitoring period.

Table 2.1 presents a summary of the flow monitoring data. The data is grouped under its corresponding major drainage basin and the following provides a description of each flow monitoring parameter:

In-situ Pipe Capacity in million gallons per day (mgd)
: This is the projected pipe full flow rate for the site under existing site conditions and a uniform flow condition. The values of existing capacity may be considerably lower or higher than design values based on pipe condition, root intrusion, silt deposition, encrustation, or pipe deterioration. The existing capacity was calculated based on flow depths and velocities recorded during the field investigation.

Average Daily Flow (mgd) - Dry (Wet)
: This is the daily average flow at a specific site location. It is determined by averaging all 15 minute flow rates (calculated from the continuity and/or Manning's equation) of the dry or wet weather analysis period.

Peak Flow Rate (mgd) - Dry
: This is the maximum flow rate which was observed during the dry weather analysis period.

Minimum Flow Rate (mgd) - Dry
: This is the minimum flow rate which occurred during the dry weather analysis period.

Peaking Ratio - Dry (Wet)
: This is the ratio of Peak Hourly Flow Rate to Daily Average Flow (also known as the peaking factor). It provides information on the variability of the wastewater flows. The closer this value is to 1.0 the less the flow fluctuates.

Peak Percent Flow Capacity Used - Dry (Wet)
: This is the ratio of Peak Hourly Flow Rate to In-situ Pipe Capacity. It is useful in evaluating the percentage of existing pipe capacity used during peak flow conditions.

Average Inflow Volume (mg)
: The wet weather inflow volume is calculated by taking the Average Daily Rainfall Dependent Infiltration/Inflow (RDII) minus the Average Daily Flow (Dry)

Table 2.1 - Wastewater Flow Data Summary

CACHE CREEK BASIN

DESCRIPTION/SITE	C102	C103	C104	C105	C106	C107	C108
In-situ Pipe Capacity (mgd)	46.401	24.884	3.586	1.541	1.814	0.603	0.796
Average Daily Flow - Dry (mgd)	8.628	1.096	0.178	0.564	0.379	0.127	0.036
Peak Flow Rate - Dry (mgd)	11.75	2.891	0.33	0.98	0.804	0.234	0.066
Minimum Flow Rate - Dry (mgd)	5.479	0.511	0.054	0.221	0.184	0.036	0.01
Peaking Ratio - Dry	1.36	2.64	1.85	1.74	2.12	1.84	1.83
Percent Capacity Used - Peak Dry	25.3	11.6	9.2	63.6	44.3	38.8	8.3
Average Daily Flow - Wet (mgd)	17.305	2.8	0.389	0.89	0.833	0.178	0.118
Average Inflow Volume (mg)	8.677	1.704	0.211	0.326	0.454	0.051	0.082
Average Discrete Inflow (mg)	1.293	1.034	0.211	0	0.454	0.051	0.082
Discrete Normalized Inflow (gal/ft/in)	8.07	14.27	2.84	0.00	3.75	0.90	2.82
Peak Flow Rate - Wet (mgd)	34.735	7.94	2.453	1.495	2.347	0.422	1.122
Peaking Ratio - Wet	4.03	7.24	13.78	2.65	6.19	3.32	31.17
Percent Capacity Used - Peak Wet	74.9	31.9	68.4	97.0	129.4	70.0	141.0
Peak Flow Depth - Dry (in)	18.275	6.924	3.836	7.996	7.35	3.773	2.98
Peak Flow Depth - Wet (in)	140.97	95.324	25.615	8.86	86.964	23.463	25.143
Pipe Diameter (in)	54	36	20.675	14.75	15	9.625	15.25
Peak Flow Depth/Diameter - Dry	0.34	0.19	0.19	0.54	0.49	0.39	0.20
Peak Flow Depth/Diameter - Wet	2.61	2.65	1.24	0.60	5.80	2.44	1.65
Pipe Footage (ft)	85850	40080	44380	48975	50100	35100	17350
Dry Weather Days	5/15-5/19	4/28-4/29	5/10-5/16	5/10-5/16	5/13-5/19	5/11-5/17	5/10-5/16
Wet Weather Days	5/6-5/7, 6/4	5/5-5/7, 6/4	5/5-5/7,6/4,6/10	5/5-5/7,6/4,6/10	6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10

DESCRIPTION/SITE	C109	C110	C111	C112	C113	C114	C115
In-situ Pipe Capacity (mgd)	1.52	0.383	0.476	3.701	4.113	2.735	2.715
Average Daily Flow - Dry (mgd)	0.24	0.051	0.229	0.803	0.785	0.221	0.054
Peak Flow Rate - Dry (mgd)	0.422	0.116	0.381	1.729	1.583	0.55	0.29
Minimum Flow Rate - Dry (mgd)	0.062	0.012	0.08	0.308	0.195	0.02	0.021
Peaking Ratio - Dry	1.76	2.27	1.66	2.15	2.02	2.49	5.37
Percent Capacity Used - Peak Dry	27.8	30.3	80.0	46.7	38.5	20.1	10.7
Average Daily Flow - Wet (mgd)	0.338	0.147	0.416	1.592	0.832	0.27	0.09
Average Inflow Volume (mg)	0.098	0.096	0.187	0.789	0.047	0.049	0.036
Average Discrete Inflow (mg)	0.098	0.096	0.187	0.706	0	0.049	0.036
Discrete Normalized Inflow (gal/ft/in)	3.30	7.56	2.98	43.93	0.00	N/A	0.54
Peak Flow Rate - Wet (mgd)	4.275	1.046	1.325	4.625	1.443	2.563	0.974
Peaking Ratio - Wet	17.81	20.51	5.79	5.76	1.84	11.60	18.04
Percent Capacity Used - Peak Wet	281.3	273.1	278.4	125.0	35.1	93.7	35.9
Peak Flow Depth - Dry (in)	7.352	1.867	14.773	9.639	6.594	2.815	2.596
Peak Flow Depth - Wet (in)	32.882	13.415	21.55	51.236	4.773	10.092	5.907
Pipe Diameter (in)	23.875	7.625	14.5	26.5	14.625	9.87	11.75
Peak Flow Depth/Diameter - Dry	0.31	0.24	1.02	0.36	0.45	0.29	0.22
Peak Flow Depth/Diameter - Wet	1.38	1.76	1.49	1.93	0.33	1.02	0.50
Pipe Footage (ft)	19900	8950	44310	10700	52950	N/A	44575
Dry Weather Days	5/14-5/20	5/19-5/15	5/10-5/16	5/11-5/17	5/11-5/17	5/14-5/20	5/8-5/13
Wet Weather Days	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7,6/4,6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10

Table 2.1 - Wastewater Flow Data Summary (Cont'd.)

SQUAW CREEK BASIN

DESCRIPTION/SITE	S201	S202	S203/S205	S204	S206	S207	S208
In-situ Pipe Capacity (mgd)	1.578	2.802	7.351	2.676	3.56	0.577	0.69
Average Daily Flow - Dry (mgd)	0.274	0.623	2.07	0.724	0.529	0.177	0.308
Peak Flow Rate - Dry (mgd)	0.586	1.242	4.355	1.139	0.845	0.308	0.498
Minimum Flow Rate - Dry (mgd)	0.132	0.28	0.275	0.356	0.233	0.055	0.123
Peaking Ratio - Dry	2.14	1.99	2.10	1.57	1.60	1.74	1.62
Percent Capacity Used - Peak Dry	37.1	44.3	59.2	42.6	23.7	53.4	72.2
Average Daily Flow - Wet (mgd)	0.681	0.949	4.141	1.44	0.854	0.375	0.568
Average Inflow Volume (mg)	0.407	0.326	2.071	0.716	0.325	0.198	0.26
Average Discrete Inflow (mg)	0.407	0.326	1.002	0.716	0.325	0.198	0.26
Discrete Normalized Inflow (gal/ft/in)	4.21	3.65	4.08	5.07	8.47	3.67	2.75
Peak Flow Rate - Wet (mgd)	2.594	3.569	6.665	3.936	1.987	0.803	1.069
Peaking Ratio - Wet	9.47	5.73	3.22	5.44	3.76	4.54	3.47
Percent Capacity Used - Peak Wet	164.4	127.4	90.7	147.1	55.8	139.2	154.9
Peak Flow Depth - Dry (in)	5.909	9.29	N/A	8.077	6.698	4.524	8.978
Peak Flow Depth - Wet (in)	17.282	36.354	N/A	83.781	59.12	7.635	82.923
Pipe Diameter (in)	15.5	23.875	24/18.625	18.25	20.75	10.25	10.125
Peak Flow Depth/Diameter - Dry	0.38	0.39	N/A	0.44	0.32	0.44	0.89
Peak Flow Depth/Diameter - Wet	1.11	1.52	N/A	4.59	2.85	0.74	8.19
Pipe Footage (ft)	66588	62845	187589	99438	28080	39901	68418
Dry Weather Days	5/10-5/16	5/12-5/18	N/A	5/14-5/20	5/11-5/17	5/13-5/19	5/16-5/20
Wet Weather Days	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	10-Jun	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10

DESCRIPTION/SITE	S209	S210
In-situ Pipe Capacity (mgd)	0.258	1.116
Average Daily Flow - Dry (mgd)	0.026	0.089
Peak Flow Rate - Dry (mgd)	0.05	0.187
Minimum Flow Rate - Dry (mgd)	0.013	0.033
Peaking Ratio - Dry	1.92	2.10
Percent Capacity Used - Peak Dry	19.4	16.8
Average Daily Flow - Wet (mgd)	0.156	0.245
Average Inflow Volume (mg)	0.13	0.156
Average Discrete Inflow (mg)	0.13	0.156
Discrete Normalized Inflow (gal/ft/in)	1.33	3.83
Peak Flow Rate - Wet (mgd)	0.576	1.245
Peaking Ratio - Wet	22.15	13.99
Percent Capacity Used - Peak Wet	223.3	111.6
Peak Flow Depth - Dry (in)	3.006	2.947
Peak Flow Depth - Wet (in)	69.024	64.984
Pipe Diameter (in)	10	10.75
Peak Flow Depth/Diameter - Dry	0.30	0.27
Peak Flow Depth/Diameter - Wet	6.90	6.05
Pipe Footage (ft)	72682	29730
Dry Weather Days	5/10-5/16	5/10-5/16
Wet Weather Days	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10

Table 2.1 - Wastewater Flow Data Summary (Cont'd.)

WOLF CREEK BASIN

DESCRIPTION/SITE	W303	W304	W305	W306	W307	W309	W310
In-situ Pipe Capacity (mgd)	9.203	2.049	14.31	5.769	0.298	11.882	12.376
Average Daily Flow - Dry (mgd)	0.782	1.045	0.472	3.783	0.1	2.796	3.759
Peak Flow Rate - Dry (mgd)	1.198	1.745	1.373	5.456	0.156	4.749	5.704
Minimum Flow Rate - Dry (mgd)	0.509	0.725	0.155	2.172	0.057	0.775	1.538
Peaking Ratio - Dry	1.53	1.67	2.91	1.44	1.56	1.70	1.52
Percent Capacity Used - Peak Dry	13.0	85.2	9.6	94.6	52.3	40.0	46.1
Average Daily Flow - Wet (mgd)	1.129	1.283	0.655	4.869	0.157	5.361	6.167
Average Inflow Volume (mg)	0.347	0.238	0.183	1.086	0.057	2.565	2.408
Average Discrete Inflow (mg)	0.109	0.055	0.183	0	0.057	0.157	0.183
Discrete Normalized Inflow (gal/ft/in)	1.88	1.17	5.52	0.00	3.28	3.54	1.22
Peak Flow Rate - Wet (mgd)	3.379	3.2	2.743	7.853	0.728	9.668	10.466
Peaking Ratio - Wet	4.32	3.06	5.81	2.08	7.28	3.46	2.78
Percent Capacity Used - Peak Wet	36.7	156.2	19.2	136.1	244.3	81.4	84.6
Peak Flow Depth - Dry (in)	6.161	11.827	3.766	26.987	5.139	18.495	15.42
Peak Flow Depth - Wet (in)	11.148	16.302	5.305	56.607	24.702	47.306	88.921
Pipe Diameter (in)	26.75	18	18	36.625	10	38	31.875
Peak Flow Depth/Diameter - Dry	0.23	0.66	0.21	0.74	0.51	0.49	0.48
Peak Flow Depth/Diameter - Wet	0.42	0.91	0.29	1.55	2.47	1.24	2.79
Pipe Footage (ft)	41789	33895	23913	20512	13356	30568	108116
Dry Weather Days	5/8-5/11	5/8-5/11	5/8-5/11	5/14-5/20	5/12-5/18	5/10-5/16	5/14-5/20
Wet Weather Days	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	10-Jun	5/6-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10

DESCRIPTION/SITE	W311	W312	W313	W314	W315	W316
In-situ Pipe Capacity (mgd)	1.186	5.903	0.993	1.5	5.059	0.725
Average Daily Flow - Dry (mgd)	0.139	0.751	1.038	0.516	0.747	0.518
Peak Flow Rate - Dry (mgd)	0.222	1.391	1.442	0.878	1.515	0.943
Minimum Flow Rate - Dry (mgd)	0.07	0.202	0.502	0.223	0.25	0.135
Peaking Ratio - Dry	1.60	1.85	1.39	1.70	2.03	1.82
Percent Capacity Used - Peak Dry	18.7	23.6	145.2	58.5	29.9	130.1
Average Daily Flow - Wet (mgd)	0.175	2.249	1.731	0.895	1.092	0.864
Average Inflow Volume (mg)	0.036	1.498	0.693	0.379	0.345	0.346
Average Discrete Inflow (mg)	0.036	0.805	0.314	0.379	0.345	0.346
Discrete Normalized Inflow (gal/ft/in)	0.99	5.10	2.30	5.20	3.00	2.23
Peak Flow Rate - Wet (mgd)	1.509	6.107	3.511	2.17	2.685	1.402
Peaking Ratio - Wet	10.86	8.13	3.38	4.21	3.59	2.71
Percent Capacity Used - Peak Wet	127.2	103.5	353.6	144.7	53.1	193.4
Peak Flow Depth - Dry (in)	2.564	8.829	15.779	8.29	6.979	12.614
Peak Flow Depth - Wet (in)	72.929	137.649	68.312	73.388	110.179	141.411
Pipe Diameter (in)	21	23.75	17.875	15.25	18	15
Peak Flow Depth/Diameter - Dry	0.12	0.37	0.88	0.54	0.39	0.84
Peak Flow Depth/Diameter - Wet	3.47	5.80	3.82	4.81	6.12	9.43
Pipe Footage (ft)	26333	113989	83275	52576	119242	98305
Dry Weather Days	5/17-5/19	5/10-5/16	6/13-6/15	5/11-5/17	5/10-5/16	5/12-5/18
Wet Weather Days	5/5-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/6-5/7, 6/4, 6/10	5/5-5/7, 6/4, 6/10	5/5-5/7	5/6-5/7, 6/4, 6/10

Average Discrete Inflow (mg)

The discrete inflow for each sub-basin was determined by taking the Average Inflow Volume less all upstream sub-basin Average Inflow Volumes.

Discrete Normalized Inflow (gal/ft/in. rainfall)

To account for variations in the rainfall across the study area and compare the inflow contribution the average discrete inflow is divided by both the linear footage within the sub-basin and the rainfall that was recorded for the sub-basin. This value provides a technique for ranking the sub-basins based on the severity of inflow per linear foot of sewer.

Peak Flow Depth (inches) - Dry (Wet)

This is the average of all daily maximum 15 minute depth recordings which occur during the dry or wet weather analysis period.

Pipe Diameter (inches)

This is the measured internal diameter of the pipeline at the monitoring site.

Peak Flow Depth/Diameter (d/D) - Dry (Wet)

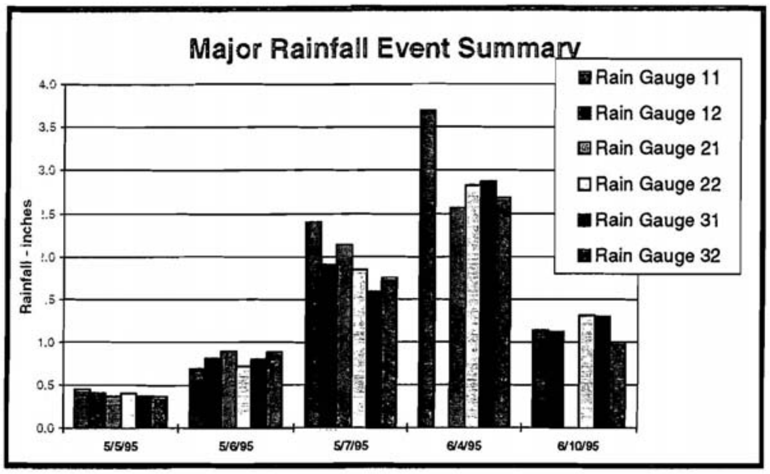
This is the ratio of Peak Hourly Flow Depth to Pipe Diameter. It is very useful in evaluating the pipe capacity being used during dry and wet weather. Values of d/D equal to or greater than 0.5 may indicate potential capacity problems.

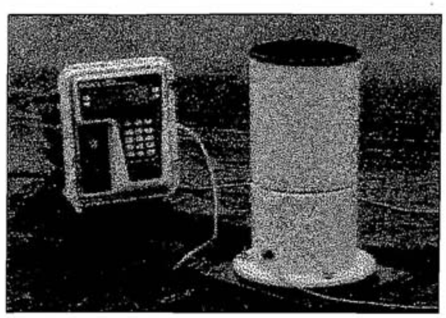
Pipe Footage (feet)

Presented is the approximate linear footage within the sub-basin.

The wet weather storm days were taken generally from the three storm events that had the greatest impact on the collection system. The first of these occurred from May 5-7, 1995 and had an average total rainfall over the collection system of 3 inches. The second occurred on June 4, 1995 and had an average total rainfall over the collection system of 2.9 inches. The third storm event occurred on June 10, 1995 and had an average total rainfall over the collection system of 1.2 inches. Figure 2.3 presents a graphical summary of these major rainfall events. These overall rainfall averages were not used for individual sub-basin calculation purposes. Instead, the rainfall for each sub-basin was determined using the Thiessen polygon method to account for the spatial variation of the six rain gauges. As a result each sub-basin had different rainfall totals used in calculating the discrete normalized inflow depending on its position relative to the surrounding rain gauges.

Analysis and evaluation of all of the sub-basins determined that the system has a





Continuous Recording Raingauge

Figure 2.3 - Rainfall Data Summary

major response to wet weather events. As Figure 2.4 typifies, the response to a wet weather storm event is very dramatic and instantaneous. In this example the flow rate increases immediately to over five times normal and slowly returns to the normal pre-storm level. From the gathered data, it is apparent that most sites exceeded pipe capacity (based on depth of flow) during one of the three major storm events and many exceeded pipe flow capacity.

In the Cache Creek basin over 80% of the inflow occurs on less than 40% of the basin area (See Figure 2.5). This means that rehabilitation efforts can be concentrated on a relatively small portion of the basin and still achieve a large percentage reduction in inflow. In the Squaw Creek Basin (See Figure 2.6), inflow was found be more uniformly distributed with approximately 80% of the inflow on 70% of the system footage. Finally, the Wolf Creek Basin (See Figure 2.7) inflow distribution was found to be 80% of the inflow on approximately 60% of the pipeline footage. Using the ratio of total inflow per inch of rain to total basin pipe footage as criteria, Cache Creek is seen to have the most severe inflow, Squaw Creek the second most severe, and Wolf Creek the least severe inflow problem. Hydrographs and detailed tabular flow data for each site are presented in the monitoring data (Volume Two).

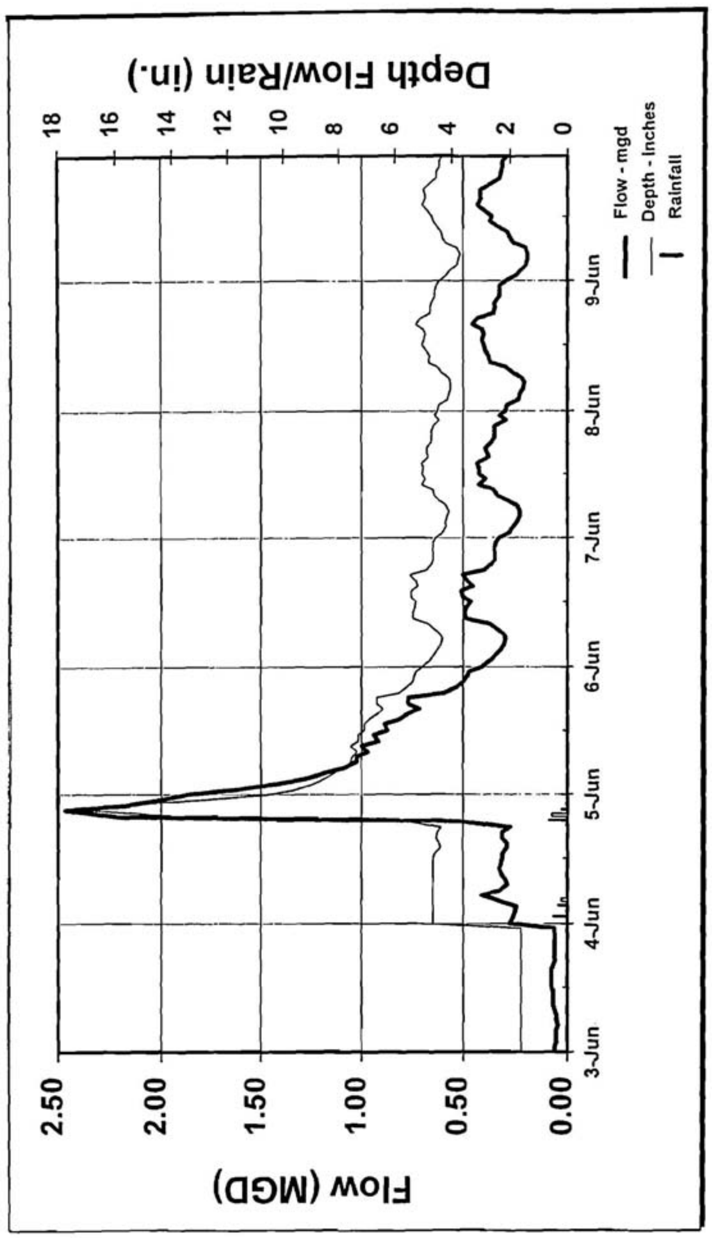
2.3 Physical Inspection

Data from the field investigations were recorded on standard forms for each of the phases of work and copies of all the database files are included in unattached field data volumes accompanying this report. The physical inspection data (Volume Three) was grouped into physical information, casting information, and interior information.

The manhole inspection field form provides for the collection of five types of data that includes: 1) general information such as the project number, crew leader identification, date of inspection, basin number, manhole number and whether or not the manhole was located and inspected; 2) physical information, such as surface conditions at manhole, manhole dimensions, length of pipe to next downstream manhole, materials of construction and a sketch illustrating the incoming and outgoing lines with proper orientation; 3) conditions of the manhole, such as defects in the various components of the manhole and evidence of infiltration/inflow and/or root intrusion; 4) environmental conditions, such as presence of gases, debris, etc.; and, 5) notes indicating unusual circumstances about a specific manhole. The pipe inspection form provides for recording the same types of information as a manhole inspection form except that it is specific to pipe conditions and defects.

A total of 6,094 manholes were inspected during this phase of the field investigation. Maps were update where necessary to visually represent the location of each manhole and connecting pipelines. Manholes were observed to vary greatly in construction and

Figure 2.4
Typical Storm Event Response



Study: Squaw Creek Basin

Daterange: 6/3/95-6/10/95
Site Name: S201
Site Address: Lee Blvd. at Drainage Ditch

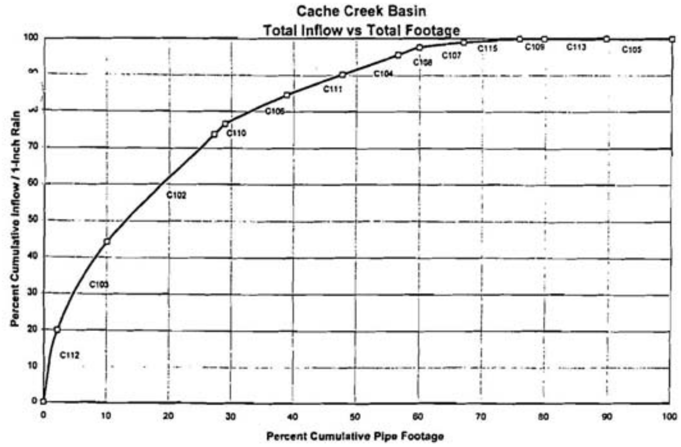
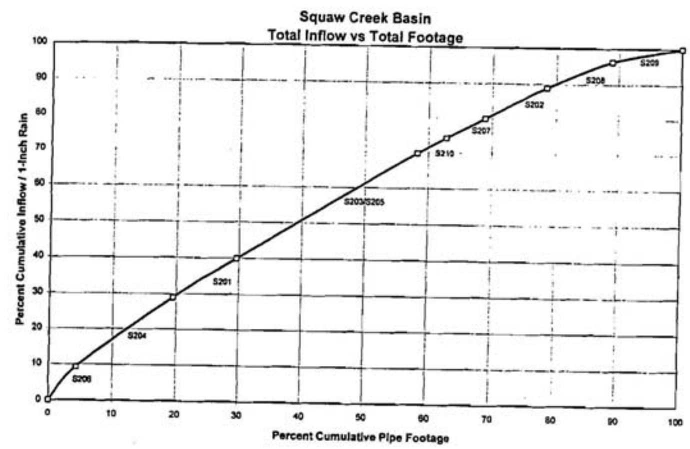


Figure 2.5
Cache Creek Basin

Figure 2.6
Squaw Creek Basin



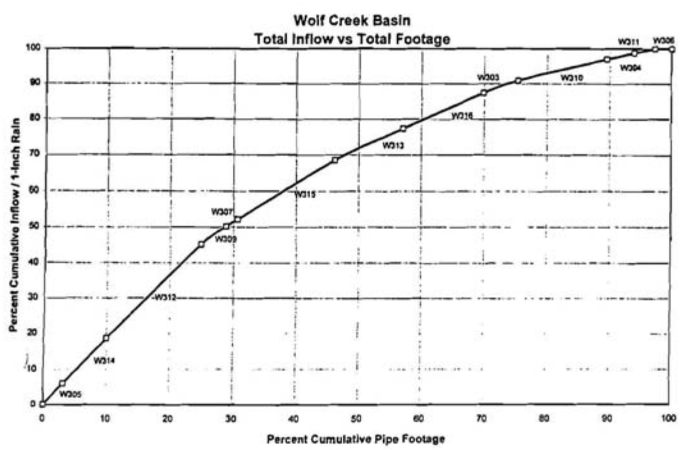


Figure 2.7
Wolf Creek Basin

degree of deterioration. Figures 2.8 and 2.9 present photographs of manholes and conditions encountered.

2.4 Smoke Testing

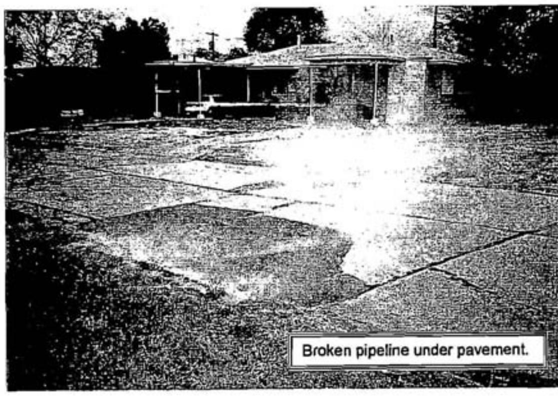
Smoke testing was undertaken on approximately 1,614,000 linear feet of gravity sewer. The observations for each line segment smoke tested were recorded on a standard smoke testing field data form. A completed smoke testing field form will contain minimal basic information, such as upstream and downstream manhole numbers to define the line segment. The remainder of the form details the defect(s) found during smoke testing. This form is supplemented by two additional sheets to provide a defect location sketch and photograph log. This information is valuable for specifying rehabilitation methods as well as for routine maintenance and contracting the rehabilitation work.

Copies of all the completed smoke testing forms are provided in Volume Four. High capacity smoke blowers were used to pressurize the test section and thereby identify system deficiencies. Figures 2.8 and 2.9 show various defects identified during the smoke testing phase of the project. The majority of defects identified during this study were located during the smoke testing phase of the project.

2.5 Internal Television Inspection

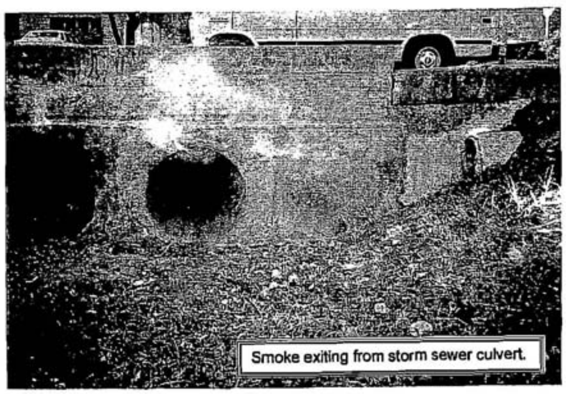
Inspection of pipes by Closed Circuit Television (CCTV) was recommended for approximately 111,000 linear feet of sewer. These lines are those where a significant or severe defect was found on a mainline during physical inspection or smoke testing.

TV logs and video tapes are provided in Volume Five. Major repairs, including the installation of liners or line replacement, has been recommended based upon the results of this work. These repairs are necessitated as a combined result of years of normal use, corrosion, and bad soil conditions evidenced by misaligned joints and "dips" in the pipe. The concrete pipeline inspected showed the most severe deterioration due to hydrogen sulfide corrosion. As the photograph in Figure 2.8 shows, much of the concrete lines have deteriorated to the point that reinforcing steel is visible and/or collapse has occurred. Figure 2.10 presents an example T.V. Log schematic diagram that visually shows the location of each observation. A pictorial review of the defects without viewing each videotape greatly improves the review and determination of repairs. Note in Figure 2.10 that the 8 inch concrete pipe has numerous cracks, offset joints, broken pipe, and at 436.9 feet the pipe transitions from 8 inch to 6 inch.



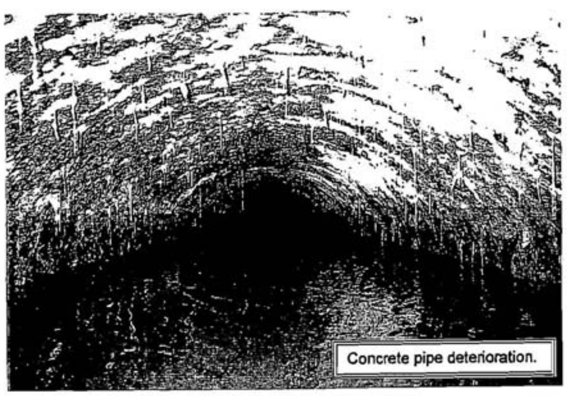
Broken pipeline under pavement.

Non-standard manhole construction. Manhole S041004M



Smoke exiting from storm sewer culvert.

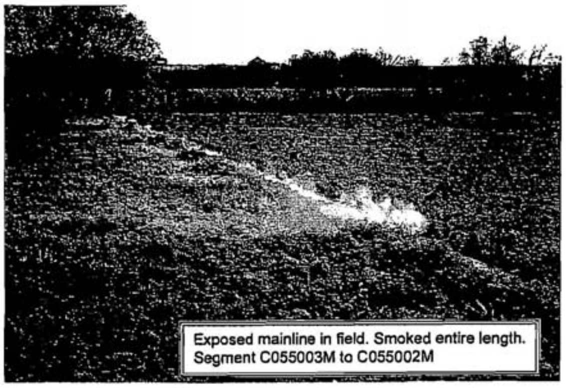
Casting separated from cone. Manhole W095009M



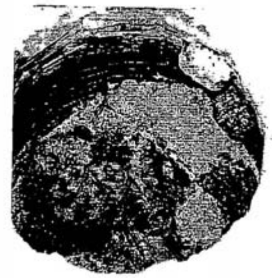
Concrete pipe deterioration.

Broken manhole casting. Manhole W036009M

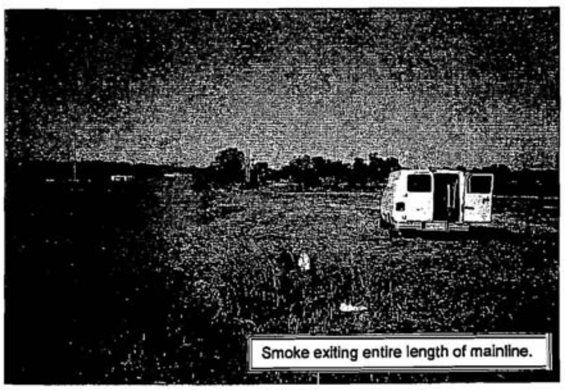
Figure 2.8
Typical Defect Photographs



Exposed mainline in field. Smoked entire length.
Segment C055003M to C055002M

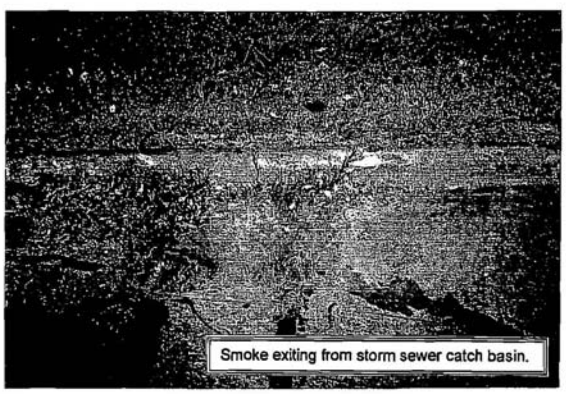


Heavy debris & grease. Manhole S026166M



Smoke exiting entire length of mainline.

Manhole S042014M fabricated from concrete pipe.
Missing manhole lid.



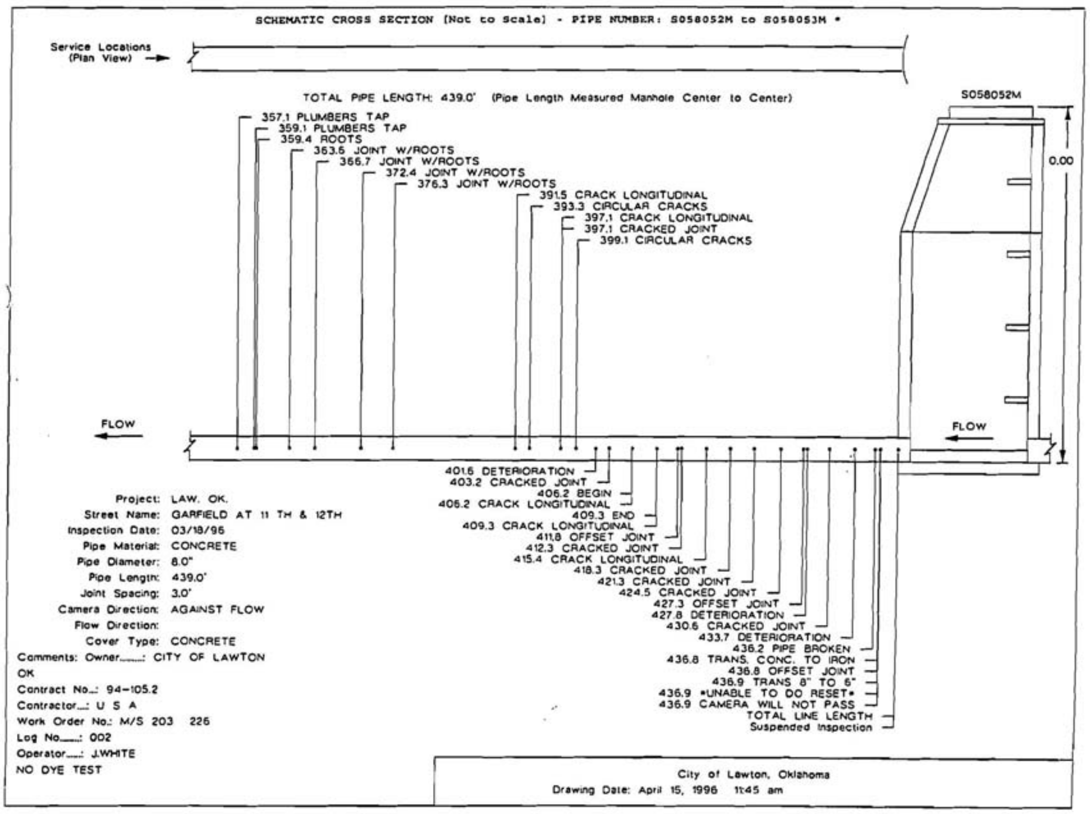
Smoke exiting from storm sewer catch basin.

Root intrusion. Manhole S026221M

Figure 2.9
Typical Defect Photographs

Figure 2.10

Internal Television Observation Schematic Diagram



2.6 Rehabilitation Methods Description

Rehabilitation methods for this project were chosen based upon the type of defects discovered, the size of the project, and the most effective methods suitable for the area. The rehabilitation methods in some instances may require specialized equipment, but most rehabilitation methods can be performed by qualified utility contractor. The conditions that determine which method should be used are found on the field forms completed during the inspections and testing. Other circumstances were considered in making a final determination on an individual asset basis for selecting the rehabilitation method, such as other rehabilitation work in close proximity to the asset being considered.

Comments placed on the field forms and photographs also provided very important information to assist in determining the most appropriate rehabilitation method. Whenever a defect was identified twice or more during different phases of the work, for example, sewer line inspection, or smoke testing, only the most complete and effective rehabilitation method was chosen between the two or more methods indicated by the different phases of the work.

The rehabilitation methods (RM) ,by reference number, are listed below with a brief description. The rehabilitation methods described are only intended to identify typical methods used in the construction industry. Specific design of these rehabilitation methods will be provided by the City's Staff Engineers or Consulting Engineer.

A. Rehabilitation Methods for Manholes

1000. Locate and Expose Manhole - Whenever Byrd Forbes Associates ("BFA") field crews cannot find a manhole this method will be recommended to let the client know that the manhole needs to be found or exposed for inspection. There is no construction cost associated with this item but it does require an expenditure of funds to accomplish, so a nominal amount per each is assessed.

1001. Locate and Raise Casting To or Above Grade - Whenever BFA field crews find a manhole that is buried this method will be recommended to let the client know that the manhole needs to be exposed for inspection. The cost basis for this rehabilitation method will be a price per each.

1010. Install Manhole Insert - Manufactured inserts should be installed below the lid of the manholes identified to prevent ponded rainwater from entering the manhole through vents in the lid. The cost basis for this rehabilitation method will be a price per each.

1020. Realign and grout casting - The casting has been loosened from the chimney or cone. The casting should be positioned properly over the chimney or cone and grouted back in place, sealing the connection to prevent leaks. In some cases the casting will be broken and should be replaced, but that condition(s) is covered below in RM 1022 and RM 1024. The cost basis for this rehabilitation method will be a price per each.

1022. Replace Casting (Frame and Lid) - This means to remove the existing casting, if one exist, and install a new one. The cost basis for this rehabilitation method will be a price per each.

1024. Replace Casting (Lid Only) - A new lid should be installed to replace a broken or missing lid. The cost basis for this rehabilitation method will be a price per each.

1030. Raise Casting To or Above Grade - This is required when a manhole is below grade, especially if it is subject to ponding or inundation. The casting should be raised to the height that would prevent it from being under significant ponding whenever possible. The amount to be raised will vary with specific site conditions. The estimated ponding depth is recorded on the Manhole Inspection Form for reference in preparation of bid request for the work. The work will consist of detaching the casting from the existing chimney or cone; constructing a new or additional chimney section a specified height; resetting the casting; and, grouting everything in place. The cost basis for this rehabilitation method will be a price per each.

1040. Clean Manhole, Repair as Needed & Coat - This is required due to missing mortar or brick, and/or severe deterioration of the manhole or a significant component of the manhole. Prior to repairs the manhole should be cleaned using a high pressure washer or manually washed to remove grease or dirt that would prevent the repair materials from adhering to the interior surface of the manhole. Repairs may consist of replacing bricks or patching concrete with a patch mix or grout. After repairs are made, the entire interior surface should be coated with special purpose waterproofing materials that are resistant to chemical degradation common to sanitary sewers. The cost basis for this rehabilitation method will be a price per vertical foot.

1042. Clean Manhole, Repair Manhole Bottom & Coat to 1' Above Pipe Crown - This is required due to missing mortar or brick around pipe penetrations or the bench, and/or deterioration of the bench, trough or pipe penetration into the manhole. Rehabilitation will be similar to RM1040 above except that it applies only to the Bench, Trough and Pipe Seal. The cost basis for this rehabilitation method will be a price per each.

1050. Stop I/I, Clean Manhole, Repair as Needed & Coat Entire Manhole - This is required when leaks are evident in the manhole; and, usually has missing mortar or brick, and/or may have severe deterioration of the manhole or a significant component of the manhole. Rehabilitation will be similar to RM1040 above except that the leaks must be stopped using packing material, chemical grout or applying exterior waterproofing compounds. The cost basis for this rehabilitation method will be a price per vertical foot.

1052. Stop I/I, Clean Manhole, Repair Manhole Bottom & Coat to 1' above Pipe Crown - This is required when leaks are evident at the Bench, Trough or Pipe Seal; and, there may be severe deterioration in that part of the manhole. Rehabilitation will be similar to RM1050 above except that it applies only to the Bench, Trough and Pipe Seal. The cost basis for this rehabilitation method will be a price per each.

1060. Remove Roots, Clean Manhole, Repair as Needed & Coat - This is required when roots are evident in the manhole; usually has missing mortar or brick, and/or may have severe deterioration of the manhole or a significant component of the manhole; and, usually leaks are evident in the manhole. Rehabilitation will be similar to RM 1040 or RM 1050 above except that the roots should be removed and a root inhibitor applied before the other repairs are made. The cost basis for this rehabilitation method will be a price per vertical foot.

1062. Remove Roots, Clean Manhole, Repair Manhole Bottom & Coat to 1' above Pipe Crown - This is required when roots are evident at the Bench, Trough or Pipe Seal; there may be severe deterioration in that part of the manhole; and, usually leaks are evident. Rehabilitation will be similar to RM1060 above except that it applies only to the Bench, Trough and Pipe Seal. The cost basis for this rehabilitation method will be a price per each.

1110. Construct or Reconstruct Manhole Invert - This is required whenever the invert has been severely deteriorated or was never constructed originally. It requires the placement and finishing of concrete while the sewage flow is being bypassed or temporarily stopped. The cost basis for this rehabilitation method will be a price per each.

1205. Structurally Repair MH Chimney and Coat Internally - Repair to the manhole chimney is required in order to restore structural integrity and internal coating is recommended to inhibit infiltration/inflow. The cost basis for this rehabilitation method will be a price per each.

1210. Structurally Repair or Replace Manhole - This is recommended for manholes that have sufficient dimension to receive the internal liner and not severely diminish access into the manhole. The City's Engineer or Consulting

Engineer may, however, elect to replace a significant part of the manhole. The cost basis for this rehabilitation method will be a price per vertical foot.

B. Rehabilitation Methods for Private Service Lines

3320. Disconnect Roof Leader - When smoke exits from the roof drains, it means that there is a direct connection of the roof drains to the service line. Normally smoke will be seen coming from the roof vents, but not the roof drains. The roof drain should be disconnected at ground level and the roof drain redirected away from the house. In addition, the disconnected portion of the roof drain should be permanently plugged. The cost for disconnecting roof drains will be a price per occurrence.

3330. Replace Missing Cleanout Cap on Private Service Line - Replace a cleanout cap that is missing. The cost basis for this rehabilitation method will be a price per each.

3340. Repair Broken Cleanout on Service Line- This applies to private service lines that have been broken and need to be repaired. It may require minor excavation to expose a section of the riser that would include the installation of a cap. The cost basis for this rehabilitation method will be a price per each.

3350. Disconnect Abandoned Service Line at Main Line - In most instances this repair method is associated with vacant property that has a service line still connected to the sanitary sewer. The abandoned service line acts as a storm drain and should be disconnected at the main line. The cost for this repair will be a price per each.

3360. Point Repair on Service Line - This is for correcting a problem on a private service line. Problems requiring this method of rehabilitation are identified by a well defined hole (flow channel) in the ground to the pipe defect revealed during smoke testing. The pipe defect(s) may include cracks in the pipe, broken pipe, dropped joint, offset joint, open joint, the invasion of roots or a defective service line connection; and may fall into one of four levels of severity (light, medium, heavy and severe). Repair consist of excavating down to the pipe and one or more of the following - replace a section (up to 15 feet) of pipe; install a sealable repair clamp; or, encase the pipe in concrete for a minimum of five feet either side of the problem(s) after sealing the problem from water leakage. Included in this RM is the proper disposal of excavated waste material such as broken pipe contaminated by the sewage. The extent of repair will be determined by the pipe depth (which is assumed to be no more than 4 feet in the cost estimates), severity of the problem and original materials of construction. The City's Engineer or Consulting Engineer will determine which type repair is most appropriate for the varying conditions locally. The cost basis for this rehabilitation method will be a price per each and will vary depending on depth.

3370. Point Repair on Service Line Under Pavement - This is for correcting a problem on a private service line; and, is exactly the same as RM 3360 above except that the repair is located under pavement which must be removed and replaced. The same conditions apply otherwise. The cost basis for this rehabilitation method will be a price per each.

3382. TV Main Line, Dye Test and Disconnect Storm Drain on Service Line - In this situation smoke exiting a surface drain may be originating from a broken service line or direct connection. In order to establish the exact repair location, it is recommended that the mainline be internally inspected while the storm drain is dye flooded. The appearance of dye in the mainline can be traced by the TV inspection crew to the service line that is defective and/or has a cross-connection with the storm sewer. Actual repair costs will be based on the price per each.

3392. TV Main Line, Dye Test and Disconnect Storm Drain on Service Line Under Pavement - This is the same repair method as described in RM3382 with the addition of cost to include excavating and repairing under pavement.

3400. Replace Section of Service Line - This is for correcting a problem on a municipal or private service sewer line. Problems requiring this method of rehabilitation are identified by multiple leaks revealed during smoke testing. The pipe defects may include cracks in the pipe, broken pipe, dropped joints, offset joints, open joints, the invasion of roots or defective service line connections; and may fall into one of four levels of severity (light, medium, heavy and severe). The rehabilitation method required is exactly the same as RM 3360 above except that the length of pipe requiring replacement is greater. The same conditions apply otherwise. The cost basis for this rehabilitation method will be a price per each and allows for the replacement of up to 50 feet of service line.

3410. Replace Section of Service Line Under Pavement - This is for correcting a problem on a municipal or private sewer line; and, is exactly the same as RM 3360 above except that the repair is located under pavement which must be removed and replaced. The same conditions apply otherwise. The cost basis for this rehabilitation will be a price per each and allows for the replacement of up to 50 feet of service line.

C. Rehabilitation Methods for Mainlines

4330. Replace Missing Cleanout Cap on Main Line - Replace a cleanout cap that is missing. The cost basis for this rehabilitation method will be a price per each.

4340. Repair Broken Cleanout on Service Line - This applies to private service lines that have been broken and need to be repaired that are located on municipal right-of-way. It may require minor excavation to expose a section of the riser that would include the installation of a cap. The cost basis for this rehabilitation method will be a price per each.

4350. Disconnect Abandoned Service Line - Whenever a house or mobile home is moved or demolished the service line is often not considered. The service line should be exposed at the right-of-way or easement line and plugged. Also included in this RM is the proper disposal of excavated waste material such as broken pipe contaminated by the sewage. The cost basis for this rehabilitation method will be a price per each.

4360. Point Repair on Municipal Line - This is for correcting a problem on a mainline or municipal service line by repairing or replacing a length of pipe less than 15 feet as in RM 3360 above except that the pipe size will usually be larger and the depth for excavation will be greater. Also included in this RM is the proper disposal of excavated waste material such as broken pipe contaminated by the sewage. The same conditions apply otherwise. The cost basis for this rehabilitation method will be a price per each and will vary depending on depth.

4370. Point Repair on Municipal Line Under Pavement - This is for correcting a problem on a mainline or municipal service line and is exactly the same as RM 4360 above except that pavement must be removed and replaced. The same conditions apply otherwise. The cost basis for this rehabilitation method will be a price per each and will vary depending on depth.

4382. TV Line, Dye Test and Disconnect Storm Drain on Mainline - In this situation smoke exiting a surface drain may be originating from a broken mainline or direct connection. In order to establish the exact repair location, it is recommended that the mainline be internally inspected while the storm drain is dye flooded. The appearance of dye in the mainline can be traced by the TV inspection crew to the defect and/or cross-connection with the storm sewer. Actual repair costs will be based on the price per each.

4392. TV Main Line, Dye Test and Disconnect Storm Drain Under Pavement - This is the same repair method as described in RM4382 with the addition of cost to include excavating and repairing under pavement.

4410. Replace Section of Municipal Service Line (Up to 50 feet) - This is for correcting a problem on a private service line that is on municipal right-of-way; and, is exactly the same as RM 3360. The cost basis for this rehabilitation method will be a price per each.

4420. Replace Section of Municipal Service Line Under Pavement (Up to 50 feet) - This is for correcting a problem on a private service line; and, is exactly the same as RM 3360 above except that the repair is located under pavement which must be removed and replaced. The same conditions apply otherwise. The cost basis for this rehabilitation method will be a price per each.

4430. Replace Entire Mainline - This is for correcting numerous problems on a mainline by replacing the entire line segment as determined from smoke testing or CCTV inspection. Re-connection of service lines is addressed in RM4435 below. The cost basis for this rehabilitation method will be a price per foot and will vary depending on depth.

4435. Reconnect Service Lines to Relayed Mainline - This work is required in association with RM4430 and includes the stub-out and short section of pipe for reconnecting service lines while the mainline is being relayed. The cost basis for this rehabilitation method will be a price per each.

4440. Replace Entire Mainline Under Pavement - This is for correcting numerous problems on a mainline by replacing the entire line segment as determined from smoke testing or CCTV inspection. This repair is the same as RM4430 except pavement must be removed and replaced. Re-connection of service lines is addressed in RM4435. The cost basis for this rehabilitation method will be a price per foot and will vary depending on depth.

4510. Clean Line, Install Cured-In-Place Pipe Liner and Open Service Connections - This RM is specified for those lines with numerous defects, as identified from internally televising the line, in congested areas where it is not desired or appropriate to excavate and relay a sewer line; and, when it is more economical than replacing the existing pipe. However, it should be recognized that any preexisting alignment flaws will not be corrected using this method of rehabilitation. Furthermore, structural deficiencies will not be eliminated or compensated for using this method. This method may be used in combination with RM 4360 or RM 4370 to eliminate impasses or severe misalignments in the pipe line in order to minimize the amount of excavation required in congested areas. This RM should only be attempted by contractors with proven experience with this specific application. The cost estimate includes the installation of the liner, including all preparatory work, and opening service connections by a remotely operated internal cutting device. The cost basis for this rehabilitation method will be a price per linear foot of pipe which will vary depending upon the pipe size, number of service connections per line segment, and restraining site conditions.

4515. Open Service Connections to CIP Liner - This includes opening service connections by a remotely operated internal cutting device after a CIP liner has been installed. The cost basis for this rehabilitation method will be a price per each.

4530. Clean Line, Install Pipe Liner By Pipe Bursting and Open Service Connections - This is a trenchless pipe replacement process where the existing pipe is hydraulically busted and the opening is enlarged to receive the same diameter or larger pipe. This RM should only be attempted by contractors with proven experience with this specific application. The cost estimate includes the installation of the liner, including all preparatory work (including pits), and reconnecting service connections. The cost basis for this rehabilitation method will be a price per linear foot of pipe which will vary depending upon the pipe size, number of service connections, restraining site conditions and the amount of roots present.

4535. Reconnect Service Lines to New Mainline - This includes reconnecting service connections by excavating down to the pipe. This RM is a point repair and is exactly the same as RM 4435. The cost basis for this rehabilitation method will be a price per each and will vary depending on depth.

5010. Clean Line and TV to Determine Line Condition and Assess Defects - This is necessary for those lines that were attempted to be televised but could not be completed due to heavy debris and/or roots. The line should be cleaned by water jetting, mechanical cutters or bucket machines, chemicals, or other means to remove debris to allow the line to be televised. The cost basis for this rehabilitation method will be a price per linear foot of pipe which will vary depending upon the pipe size, site restrictions and the amount of debris present.

3.0 System Modeling and Hydraulic Analysis

A practical method of analyzing a sewer system as large and complex as the City of Lawton's system is to develop a computer model which closely simulates the actual system. A calibrated computer model provides an efficient means to assess the existing system and is also beneficial in determining methods of upgrading the system and planning for future system expansions.

The computer model chosen for the City of Lawton's study was the HydroWorks

Software. This software can model complex networks of nodes (manholes), links (pipes), and structures (pump, weirs), in addition to simulating full backwater effects, reverse flow, and collection system overflows.

Hydraulic behavior in sanitary sewer systems is principally a function of the following parameters:

- Physical Characteristics of the system network (e.g., pipe length, pipe slope, pipe diameter)
- Pipe Material
- System Configuration
- Sewer Service Basin size and orientation
- Type and Locations of System Defects

To model and analyze the existing sewer system, a network of all 10 inch and larger lines was constructed from data obtained through physical inspection and field surveys. The information included pipe diameter, pipe length, pipe invert elevation, manhole rim elevation, and manhole depth.

Once the network was constructed, a continuity check was performed to ensure that all pipes were properly connected and accounted for in the model.

The model consists of 1,476 line segments of 10" and larger diameter pipe for a total of approximately 493,000 linear feet.

3.1 System Dry Weather Capacity (Existing)

In order to evaluate the existing system on an average dry weather day (no wet weather inflow), the system was sectorized into 220 service areas. Utilizing Lawton's 1990 Census Data, the population density (persons/acre) was determined for each service area. In addition, each service area was assigned one of five land use categories designated as 100% - 0% residential to 0% - 100% commercial. This land use category was then used to develop a dry weather hydrograph for each of the service areas.

From flow meter data, the flow per capita was determined for each of the five land use categories, and the flow was input into the model utilizing the dry weather hydrographs.

Calibration of the model was accomplished by adjusting the hydrographs and/or the per capita flow, to match the actual field measured flow data at each metering site.

The model showed that during dry weather conditions, the existing system has adequate capacity to convey the wastewater to the treatment plant without overflows. However, it should be noted that a few of the line segments are at capacity or operate in a surcharge condition. (Figure 2-Appendix "A"). Typically, if a line segment has flow at or above its carrying capacity, the line segment immediately upstream of it will show to be surcharged. In addition, lines with reverse grades will also show as being surcharged.

3.2 System Dry Weather Capacity (2020 Plan)

Utilizing the 2020 Plan prepared by the City of Lawton, additional dry weather flows were input into selected portions of the system based on projected population and industrial growth within the City.

An average residential flow of 110 gallons per capita per day (GPCD) was added for population increases and an average of 900 gallons per acre per day (GPAD) was added for future industrial growth. These additional flows were input through the dry weather hydrographs to evaluate the collection system capacity as the City grows from its current population of 86,800 to the projected population of 110,000 in the year 2020.

The model showed that the existing system with future flows has adequate capacity to convey the wastewater to the treatment plant without collection system overflows. However, portions of the system along the South Wolf Creek Basin trunk main will be operating at capacity and in surcharged conditions. (Figure 3-Appendix "A").

Because no sewer collection system is totally unaffected by wet weather conditions, it is desirable to have excess system capacity during normal dry weather flow conditions so that any extraneous water entering the system during wet weather can be conveyed without overflows.

3.3 System Wet Weather Capacity (2-Year/24-Hour)

To evaluate the impact that wet weather has on the collection system, measured flows were analyzed from three storm events that had the greatest impact on the system. These storms occurred on May 5-7, 1995, June 4, 1995 and June 10, 1995, with rainfall ranging from 1.2 inches to 3.0 inches in a 24 hour period.

With the June 4, 1995 storm showing to have the greatest impact on the system, the flow data from this storm was selected for wet weather calibration of the model.

Inflow hydrographs were developed and utilized to input wet weather flows into the model. The measured inflow volume for each metered sub-basin was represented by a runoff percentage factor based on the total area of the sub-basin. For example, a one percent runoff factor could result in one percent of the measured sub-basin rainfall entering the sewer collection system.

The measured inflow volume from each sub-basin was then distributed throughout the system on a weighted basis depending on the size of the contributing service area. The model was calibrated for wet weather flows by adjusting the run-off factor to match the actual field measured data at each metering site for the June 4, 1995 event.

In an attempt to determine a reasonable level of protection relative to system wet weather overflows, ten years of historical rainfall data was analyzed for the Lawton area. It was determined that only on three occasions since January, 1987 did the maximum 24-Hour rainfall exceed a total of 3.69 inches (Figure 4-Appendix "A"). This total is statistically the 2-Year 24-Hour storm event.

Based on this historical information, it was recommended that the collection system be capable of conveying wet weather flows induced by 3.69 inches of rain over a 24-Hour period. This recommendation was agreed to by the City of Lawton and on December 31, 1996 a meeting was held in the offices of the Oklahoma Department of Environmental Quality (ODEQ) for the purpose of obtaining approval for the selected storm. As a result of this meeting, ODEQ granted the City approval for a 2-Year 24-Hour design storm.

To model this condition, rainfall amounts were increased within each sub-basin to 3.69 inches in a 24 hour period with the runoff factors remaining the same as utilized in the calibrated wet weather model.

The model showed that during this storm event more than 75% of the modelled system is at capacity or under surcharged conditions. More significant is the fact that there are more than twenty-eight (28) overflow areas within the collection system (Figure 5-Appendix "A").

3.4 System Design Storm Capacity (2-Year/24-Hour & 2020 Plan)

For the purpose of recommending collection system improvements, the system was modelled under the ODEQ approved storm in addition to projected future flows based on the 2020 Plan.

This selected "Design Storm" simulation showed that more than 80% of the modelled system is at capacity or surcharged. (Figure 6-Appendix "A")

Under the design storm conditions the existing collection system cannot convey wastewater to the treatment plant without experiencing sewage overflows in over thirty (30) areas throughout the system. (Figure 7-Appendix "A")

4.0 System Rehabilitation Recommendations

In an attempt to reduce the total system wet weather inflow by 25% to 30% and to enhance the long-term structural integrity of the existing system, an extensive rehabilitation and repair program is recommended to specifically address public collection system mainlines, collection system manholes, and private service lines.

In the past, a detailed cost-effective analysis was performed relative to repair or replacement. However, due to the conditions of the existing system and the lack of capacity, the recommended repair virtually provides for replacement of the collection lines as the repair method. Therefore, a cost-effective analysis is not applicable.

With a very aggressive public/private rehabilitation program, it is possible to achieve the follow inflow reduction percentages.

Public Mainlines -	26% Inflow Reduction
Private Service Lines -	21% Inflow Reduction
Manholes -	5% Inflow Reduction

However, past experience has shown that cities will not expend public funds to repair private service lines, and they have not been insistent on the property owners properly repairing the private service defects. Consequently, system inflow reduction rates (volume) typically range from 25% to 30%.

From the field investigation results of the physical inspection, smoke testing, and internal T.V. inspection, system defects which act as sources of wet weather inflow were identified. With priority given to eliminating the modelled overflows shown in Figure 7- Appendix "A", it is recommended that all rehabilitation work be completed first in Squaw Creek Basin, then in Wolf Creek Basin, and finally in Cache Creek Basin.

Only those defects which were determined to contribute to system overflows have been scheduled for repair. However, as funds become available the City should repair the hundreds of other documented defects before they become inflow sources. Also, shown in Appendix "E" is a listing of high maintenance line segments. A number of the segments are already scheduled for repair, however, those that are not scheduled should be addressed by the City.

In addition it is recommended that the City of Lawton establish and maintain an aggressive preventative sewer maintenance program so that every line in the collection is cleaned/T.V. inspected on a 5 year cycle. With 2,300,000 linear feet of sewer line, this will require the City to clean/T.V. inspect over 400,000 linear feet of line per year.

A map showing the sub-basins and the rehabilitation program phases is included in Figure 8- Appendix "A".

4.1 Manhole Rehabilitation

It is estimated that defective manholes may count for approximately 10% of the wet weather inflow into the collection system.

The recommended methods for repair and rehabilitation of selected manholes include complete replacement, lid/frame repair, lid replacement, coating/waterproofing of walls, cones, and chimneys, and manhole patching.

Approximately 1625 manholes are recommended for rehabilitation/repair throughout the collection system.

In Appendix "B" detailed Rehabilitation Tables provide a listing of each manhole to be repaired, depth of manhole material, recommended rehabilitation method, priority ranking, and construction cost for repair. This analysis should be used as a guide and as detailed rehabilitation/repair plans and specifications are prepared, each manhole should be inspected to validate the recommended repair method.

It is recommended that each of the 1625 manholes as outlined in Appendix "B" be rehabilitated/repaired to remove the potential for wet weather inflow into the collection system.

4.2 Main Collection Lines Rehabilitation

It is estimated that 50% of the wet weather inflow may enter the collection system through defective portions of the public mainline system. The recommended methods for repair and rehabilitation include complete replacement, partial line segment replacement, point repair, and liner installation.

Portions of approximately 973 mainline segments throughout the system are recommended for rehabilitation/repair. Therefore approximately 191,000 linear feet of mainline will require some form of repair work.

In Appendix "C" detailed Mainline Rehabilitation Tables provide a listing of each line segment to be repaired, the pipe size, pipe length, pipe material, priority ranking, the recommended rehabilitation method, and construction cost for the repair. This analysis should be used as a guide, and as detailed rehabilitation/repair plans and specifications are prepared, each line segment should be inspected or re-evaluated to validate the recommended repair method.

It is recommended that each of the 973 mainline segments as outlined in Appendix "C" be rehabilitated/repaired to remove the potential for wet weather inflow into the collection system.

4.3 Private Service Lines Rehabilitation

It is estimated that 40% of the wet weather inflow may enter the collection system through defective portions of private service lines. The recommended methods for repair include partial line replacement, point repairs, plugging abandoned services, installing cleanout caps, and disconnecting roof drains.

Approximately 2,109 private lines throughout the system are recommended for rehabilitation/repair.
In Appendix "D" detailed Rehabilitation Tables provide a listing for each private service line segment to be repaired, the recommended repair method, and construction cost for repairs.

Private service defects should be addressed to reduce the volume of extraneous water entering the system. Notification of the various private residents to make the necessary repairs should be performed diplomatically, yet with emphasis on the importance of each repair. Quality control and proper follow-up is recommended to ensure that repairs are made according to the recommendations. Private property owners that refuse to make the necessary repairs and/or make improper repairs should be addressed by the appropriate authority of the City.

It is recommended that each of the 2,109 private lines as outlined in Appendix "D" be rehabilitated/repaired by the private property owners to remove the potential for wet weather inflow into the collection system.

5.0 System Expansion Recommendations

Based on the hydraulic model, the existing collection system under Design Storm Conditions (2-Year.24-Hour & 2020 Plan), cannot convey the wastewater to the treatment plant without widespread collection system overflows. Even with 25% to 30% inflow reduction taken for the extensive rehabilitation program, additional line capacity will be required to convey the remaining post-rehabilitation design storm flows in addition to providing for future growth based on the City's 2020 plan.
Approximately 92,500 linear feet of line throughout various portions of the system is recommended for expansion/upgrade.

It should be emphasized that the hydraulic model is based on the modelled lines being clean with no deposition within the pipe inverts. If the lines are not maintained and cleaned periodically the model results may not be accurate.

Also, with the increased collection system capacity as a result of the upgrade and expansion projects, it is recommended that a new 15,000,000 gallon wet weather facility be constructed at the existing wastewater plant to accommodate wet weather flows entering the plant. This new facility will have the capacity to handle flows based on a 5-Year storm in accordance with ODEQ requirements.

On the following page in priority order is a summary description of each recommended expansion/upgrade project and the new wet weather facility. Also a map showing the proposed system expansion/upgrade improvements and the wet weather facility is included as Figure 9-Appendix "A".

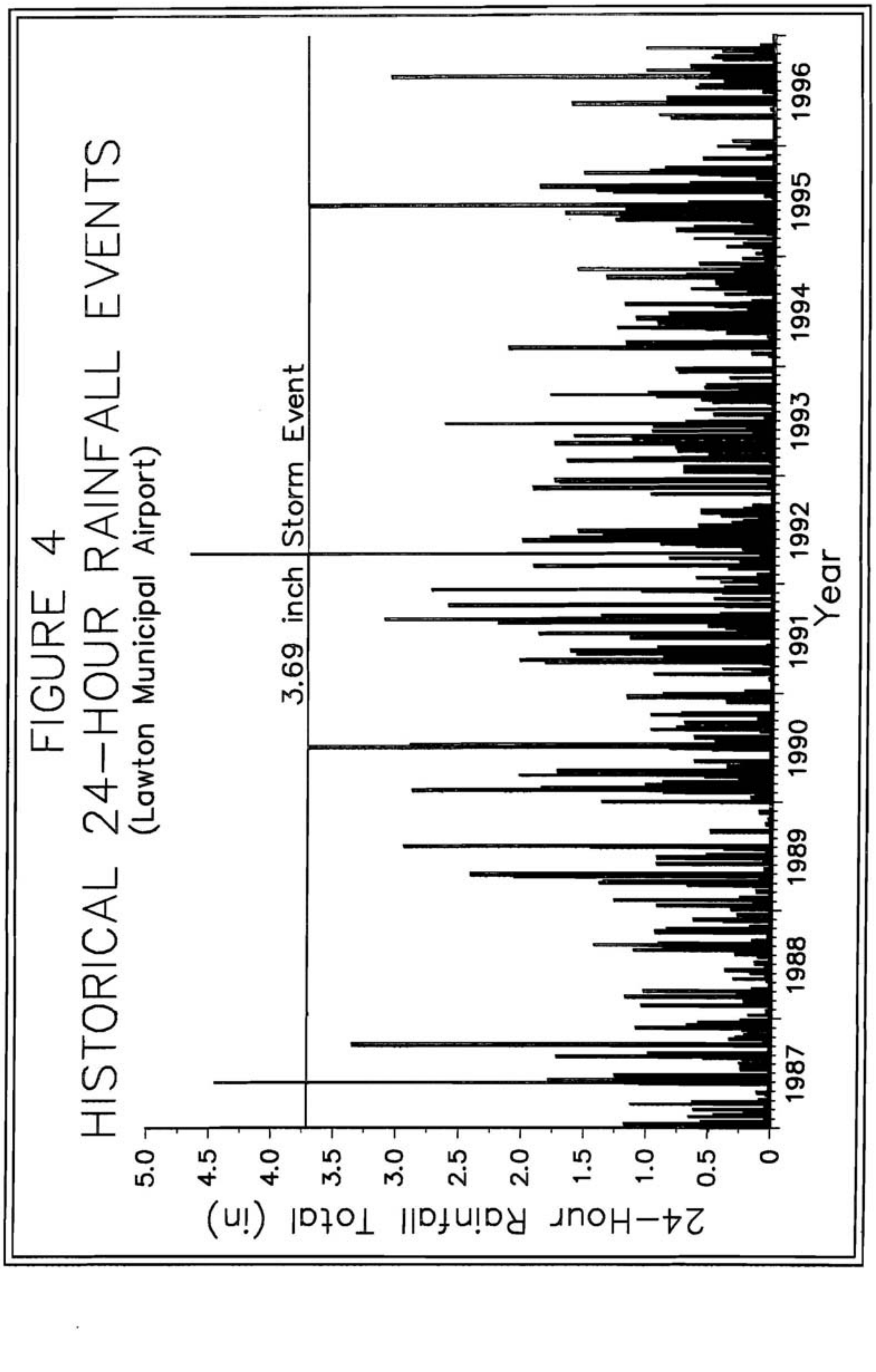


FIGURE 4
HISTORICAL 24-HOUR RAINFALL EVENTS
(Lawton Municipal Airport)
3.69 inch Storm Event
24-Hour Rainfall Total (in)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year

SYSTEM EXPANSION/UPGRADE PROJECTS

Project Name	Location (Manhole to Manhole)	Description	Estimated Construction Cost
1. Bishop Rd. Interceptor	S057019M to C056027M	Construct New 36" Line	$ 525,000
2. Park Ave. Upgrade	S040122M to S042055M	Upgrade 18" to 27" Line	950,000
3. Carver St. Upgrade	C024046M to C024037M	Upgrade 12" to 15" Line	250,000
4. Arnold Park Expansion	C024037M to S024323M	Parallel 12" w/15" Line	300,000
5. Sheridan Rd. Upgrade 1	S026091M to S040122M	Upgrade 15" to 21" Line	350,000
6. Wet Weather Facility	Treatment Plant	15MG Wet Weather Facility	2,250,000
7. Sheridan Rd. Upgrade 2	S011025M to S026091M S026178M to S026091M	Upgrade 10" to 12" Line	400,000
8. S.W. 24th Upgrade	S027854M to S040122M	Upgrade 18"/21" to 24"/27" Line	525,000
9. Arlington Ave. Upgrade	S027177M to S027105M	Upgrade 10" to 12" Line	350,000
10. N.W. 23rd/26th St. Upgrade	S010210M to S027232M S010014M to S026091M	Upgrade 10"/12" to 12"/15"/18" Line	675,000
11. West Gore Blvd. Upgrade	W039175M to W028002M	Upgrade 10" to 12" Line	225,000
12. N.W. 62nd St. Upgrade	W029152M to W029049M	Upgrade 10" to 12" Line	225,000
1) * 13. N.W. 43rd St. Upgrade	W009105M to W009020M	Upgrade 10" to 12" Line	300,000
14. N.E. Rogers Lane Upgrade	C011214M to C013657M	Upgrade 10" to 12"/15" Line	600,000
15. S.E. "D" Ave. Upgrade	C043047M to C043046M	Upgrade 8" to 10" Line	175,000
* 16. N.W. 75th St. Upgrade	W007122M to W007097M W007005M to W030033M	Upgrade 12"/15"to 15"/18" Line	650,000
17. South Wolf Creek Trunk Expansion 1	W085012M to C096014M	Parallel 36" w/ 42" Line	2,600,000
18. South Wolf Creek Trunk Expansion 2	W086009M to W085012M	Parallel 27"/30" w/30"/36" Line	1,850,000
19. North Wolf Creek Interceptor	W069018M to W069004M	Construct New 27" Line	450,000
20. North Wolf Creek Expansion 1	W039013M to W069018M	Parallel 36"/30"w/24" Line	1,350,000
21. North Wolf Creek Expansion 2	W028021M to W039013M	Parallel 30" w/24" Line	1,400,000
22. North Wolf Creek Expansion 3	W030031M to W028021M	Parallel 18"/21"/24"w/ 18"/24" Line	1,400,000
23. Rock Island R.R. Upgrade	S058005M to S042012M	Upgrade 10" to 15"/18" Line	950,000
24. South Wolf Creek Expansion 3	W086012M to W086009M	Parallel 27" w/ 30" Line	1,500,000
25. South Wolf Creek Expansion 4	W038097M to W006012M	Parallel 21"/18" w/30"/24" Line	1,350,000
26. South Wolf Creek Expansion 5	W036009M to W038097M	Parallel 18" w/ 24" Line	1,350,000
		TOTAL ESTIMATED CONSTRUCTION COST	$ 22,950,000

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6.0 Final Report Closure

Throughout a twenty-two month period, beginning in April, 1995, extensive field tests were performed in an effort to define, identify, and document deficiencies within the City's sewer collection system.

After a thorough analysis and evaluation of all the results and findings from the study, the following observations and conclusions are offered:

- Dry weather capacity problems do exist; however, with the exception of frequent line stop-ups, dry weather flows are conveyed to the treatment plant without overflows.
- Wet weather inflow entering defective portions of the collection system does impact the system and causes sanitary sewer overflows.
- The City should initiate, as outlined in this study report, an aggressive and comprehensive rehabilitation/repair program in an attempt to reduce the wet weather inflow by 25% to 30%.
- Sanitary sewer overflows cannot be eliminated by system rehabilitation/ repair work alone.
- The City should provide for selected area expansion/upgrade of lines, as outlined in this study report, to adequately convey the ODEQ approved Design Storm (2 Year/24-Hour & 2020 Plan).
- All recommended collection system rehabilitation/repair work should be completed throughout the system by December, 2014.
- Flow monitoring should be conducted periodically throughout the rehabilitation/repair program to assess and document the inflow reduction results.
- Along with the collection system rehabilitation/repair program, the recommended system expansion/upgrade lines should be constructed.
- All recommended collection system expansion/upgrade lines should be completed and in operation by December, 2018.
- The City should begin by May 1, 1997 their preventative sewer maintenance program so that the complete system is cleaned at least every 5 years.
- As funds become available the City should address the high maintenance line segments listed in Appendix "E". Consideration should be given to replacement of these lines.

7.0 Cost Estimates and Schedule

A comprehensive rehabilitation and expansion program has been defined in the previous sections of this report. With the recommended scope of work generally consisting of extensive city-wide collection system rehabilitation followed by field flow monitoring for confirmation of adequate repairs as well as major system expansion/upgrade construction, it is imperative that the City adopt a realistic multi-year financial plan and construction schedule.

To assist in developing a financial plan, cost estimates were prepared for all recommended rehabilitation and system expansion/upgrade work. These cost estimates which include construction, design engineering, inspection, and contingencies are presented in the following portion of this report section.

Additionally, a multi-year improvements schedule was developed which established completion dates for various phases of the work. In preparing the schedule, priority was given to completing all the rehabilitation work in areas that experience the most frequent overflows.

However, it must be understood that as field conditions change or additional information is gathered from the cleaning program, the City should make necessary schedule modifications.

The majority of rehabilitation work to repair collection system defects for the reduction of wet weather inflow is scheduled for completion within the first 12 years, with the remaining inflow reduction work completed by the year 2014. The expansion/upgrade projects will be done in conjunction with the rehabilitation program and all expansion/upgrade work be completed by the year 2018.

In developing the improvements schedule, serious consideration was given to the impact that this large amount of construction work would have on the City staff, construction costs, and the local community. It was determined that scheduling the work over a twenty-year period would be the most beneficial due to the following:

- The City could provide the necessary construction administration and inspection, with a minimal staff increase.
- Community disruption due to the construction work could be kept to a tolerable level.
- Construction work could be uniformly distributed, thereby providing a basis to help maintain stable construction costs.
- Additional field flow monitoring could be performed to confirm results of the rehabilitation/repair work and adjust scope of work as necessary.

Based on the above, it is recommended that the City of Lawton adopt the Sanitary Sewer Overflow ("S.S.O.") Abatement Schedule as presented in this report section.

SYSTEM REHABILITATION/EXPANSION COST SUMMARY

SYSTEM REHABILITATION/EXPANSION COST SUMMARY

Item	Quantity	Estimated Cost
Manhole Rehabilitation	1,625 EA	$ 698,000
Mainline Rehabilitation	191,000 LF	18,986,000
System Expansion/Upgrade	92,500 LF	20,700,000
Wet Weather Facility	15MG 1-EA	2,250,000
	Sub-Total (Construction)	$ 42,634,000
Engineering and Inspection	LS	4,466,000
Contingencies	LS	5,460,000
	Sub-Total (Engineering and Contingencies)	$ 9,926,000
City Maintenance Identified Rehabilitation	LS	7,500,000
Administration of Private Service Rehabilitation	LS	680,000
Flow Monitoring Assessment	LS	510,000
	Estimated Grand Total	**$ 61,250,000**

SYSTEM REHABILITATION/EXPANSION ANNUAL COST SUMMARY

Year	Manhole Rehabilitation (Const. Cost)	Mainline Rehabilitation (Const. Cost)	Private Service Rehabilitation Administration	Expansion/ Upgrade (Const. Cost)	City Maintenance Identified Rehabilitation	Flow Monitoring Assesment	Engineering/ Inspection/ Contingencies	Total Estimated Annual Cost
1998	$ 3,000	$ 764,000	$ 85,000	$ 1,475,000	$ 375,000	$ 0	$ 519,000	$ 3,221,000
1999	42,000	1,542,000	85,000	0	375,000	30,000	376,000	2,450,000
2000	44,000	1,687,000	85,000	0	375,000	30,000	428,000	2,649,000
2001	19,000	1,169,000	85,000	550,000	375,000	30,000	420,000	2,648,000
2002	22,000	750,000	85,000	2,600,000	375,000	30,000	786,000	4,648,000
2003	20,000	1,590,000	85,000	400,000	375,000	30,000	481,000	2,981,000
2004	54,000	2,231,000	85,000	0	375,000	30,000	536,000	3,311,000
2005	74,000	1,493,000	85,000	525,000	375,000	30,000	488,000	3,070,000
2006	56,000	1,780,000	0	350,000	375,000	30,000	510,000	3,101,000
2007	86,000	1,233,000	0	675,000	375,000	30,000	467,000	2,866,000
2008	74,000	687,000	0	750,000	375,000	30,000	351,000	2,267,000
2009	16,000	444,000	0	775,000	375,000	30,000	286,000	1,926,000
2010	17,000	1,158,000	0	650,000	375,000	30,000	422,000	2,652,000
2011	47,000	742,000	0	2,600,000	375,000	30,000	790,000	4,584,000
2012	33,000	413,000	0	2,300,000	375,000	30,000	639,000	3,790,000
2013	13,000	436,000	0	1,350,000	375,000	30,000	375,000	2,579,000
2014	78,000	867,000	0	1,400,000	375,000	30,000	544,000	3,294,000
2015	0	0	0	1,400,000	375,000	30,000	322,000	2,127,000
2016	0	0	0	2,450,000	375,000	0	564,000	3,389,000
2017	0	0	0	1,350,000	375,000	0	311,000	2,036,000
2018	0	0	0	1,350,000	0	0	311,000	1,661,000
TOTAL	$ 698,000	$ 18,986,000	$ 680,000	$ 22,950,000	$ 7,500,000	$ 510,000	$ 9,926,000	$ 61,250,000

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City of Lawton

Sewer Construction Division

E-mail: cityof.lawton.ok.us
Telephone 580-581-3405
Fax 580-581-3488

Mailing Address: 103 Southwest
Shipping Address: 2100 South
Lawton, Oklahon

March 9, 1999

Paul Hodge
Assistant Chief
Financial Assistance Division
State of Oklahoma
Water Resources Board
3800 North Classen Boulevard
Oklahoma City Oklahoma 73118

Dear Mr. Hodge:

Enclosed please find the following:

- "Revised" Cost Effective Analysis of the Citywide Sanitary Sewer Collection System Rehabilitation as requested.
- ODEQ Permit No. SL000016991252 - includes projects 98-1 SSES (FY 98/99 CDBG); 98-2 SSES (Bishop Road 36"); 98-5 SSES & 98-6 SSES (Sub-basin 206 Rehab); and 98-7 SSES (NW 75th Street Emergency Upgrade).

If you have any questions or require any additional information, please contact me at 580-581-3324.

Sincerely,

Roger L. Bridges

Roger L. Bridges, P.E.
SSTD Civil Engineer

Enclosure

cc: Jerry Ihler
Rusty Whisenhunt
Steve Livingston

City of Lawton
Sewer Construction Division

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Lawton, Oklah

Cost Analysis

The cost analysis used to determine the best method for preventing sanitary sewer system over flow as required by the EPA Administrative Order and the ODEQ Consent Order is as follows:

The SSES Final Report identified that an additional 28,000,000 gallons of extraneous water is received at the treatment plant during a 2" to 3.7" rain event in a 24 hour period. During flow monitoring of the collection system, it was determined that flow did increase due to I&I by 28,000,000 mg during a storm event on June 4, 1995 of 2.9 inches. After negotiations with ODEQ and EPA, it was agreed that the City of Lawton would design its improvements to accommodate a 2 year/24 hour storm event of 3.64 inches (Figure 4 in SSES Report). Figure 5 of the SSES Report shows locations of the sewer system overflow areas (approximately 28) with much of the system surcharged. From the report, information obtained indicated a cost analysis could be performed to determine the most economical method of correcting the City of Lawton I&I problem.

Option I

Inflow and infiltration reduction 0%

Current capacity of WWTP 10 mgd

Current average day flow 9.5 mgd

Conclusion: To treat the I&I at the treatment plant, capacity would have to be increasec to 38 mgd average daily flow (ADF).

Cost for Expansion of 28 MGD

Design of expansion, 6% of construction cost	$3,780,000
*Construction cost $2.25/gallon x 28,000,000	$63,000,000
Purchase of land, 20 acres @ $1,500/acre	$30,000
Operation cost over 20 year period	
Annual operation cost $1.5 million/year	
Assume annual inflation rate of 2.5% and annual interest rate of 5% which provides a net of 2.5% (5% - 2.5%).	
PW = 1,500,000 x $(1-(1+2.5\%)^{-20})/2.5\%$	$23,383,743
Transportation Cost	$22,950,000
All expansion projects listed in the SSES report would be required to transport flow	
Total cost to treat and transport with 0% reduction of I&I	$113,143,743

Note: $2.25/gallon is the cost obtained from the current expansion project at the Wastewater Treatment Plant. $1,500/acre is the appraised value of land adjacent to the current plant operation. Transportation cost is estimated in the SSES Final Report.

Operation cost of $1,500,000 is based on the actual budget expense for the City of Lawton's existing Wastewater Treatment Plant. The increase of 28 mgd will require a second complete plant operation, not upgrade of the existing plant facility.

Option II

Inflow and infiltration reduction of 25%

Increase treatment capacity to 18 mgd average daily flow. This work was already required due to current capacity at 95% of ADF.

Design cost, 6% of construction cost $1,100,000
Cost of expansion of 8 mgd $17,600,000
No purchase of land necessary $0
Annual operation cost over 20 years @ $200,000/year

Assume annual inflation rate of 2.5% and annual interest rate of 5%, which provides a net rate of 2.5% (5% - 2.5%).

$PW = 200{,}000 \times (1-(1+2.5\%)^{-20})/2.5\%$ $3,117,800

Transportation cost and upgrade cost $61,250,000
Total Cost $83,067,800

Note: $17,600,000 is the actual contract amount for the expansion of the plant to 18 mgd ADF. The $200,000/year operation cost is due to the increase in electrical power demand. No other additional cost is projected over current operation budget. Transportation cost and upgrade cost is the amount estimated in the SSES Final Report.

Option III

Inflow and infiltration reduction 50%

The increase in treatment capacity to minimum 15 mgd average daily flow is required due to current treatment capacity of 95% ADF.

Design Cost, 6% of construction cost	\$1,000,000
Cost of expansion of 5 mgd	\$15,600,000
No purchase of land necessary	\$0
Annual operation cost over 20 years @ \$180,000/year	
Assume annual inflation rate of 2.5% and annual interest rate of 5%, which provides a net rate of 2.5% (5% - 2.5%).	
$PW = 180{,}000 \times (1-(1+2.5\%)^{-20})/2.5\%$	\$2,806,050
Transportation cost and upgrade cost previously identified 250,000 lf of line	\$61,250,000
Additional line rehabilitation 400,000 lf of line	\$40,000,000
Total cost	\$120,656,050

Note: The expansion costs used were costs provided by CH2M Hill, Inc. to increase the existing plant capacity to 15 mgd ADF. Cost to rehabilitate line @ \$100/lf, size range is 8" to 24". Operation cost of \$180,000 is based on additional operation cost projected for upgrade of the existing Wastewater Treatment Plant.

Option IV

Inflow reduction of 75%

Increase of treatment capacity to 15 mgd average daily flow is required due to current treatment capacity of 95% ADF.

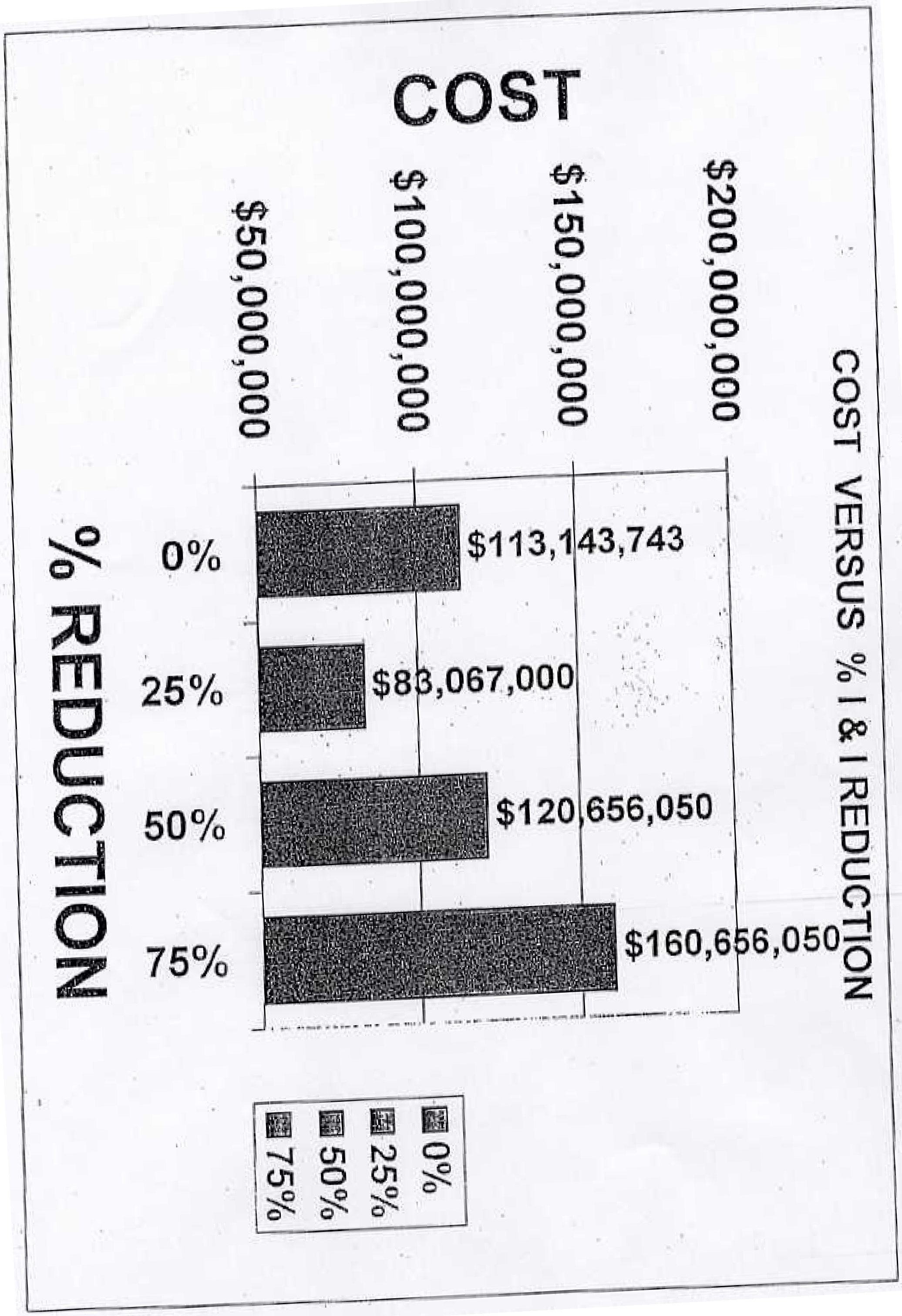
Design cost, 6% of construction cost	\$1,000,000
Cost of expansion of 5 mgd	\$15,600,000
No purchase of land necessary	\$0
Annual operation cost over 20 years @ \$180,000/year	
Assume annual inflation rate of 2.5% and annual interest rate of 5%, which provides a net rate of 2.5% (5% - 2.5%).	
$PW = 180{,}000 \times (1-(1+2.5\%)^{-20})/2.5\%$	\$2,806,050
Transportation cost and upgrade cost previously identified 250,000 lf of line	\$61,250,000
Additional line rehabilitation 800,000 lf of line	\$80,000,000
Total cost	\$160,656,050

Note: Current plant operating at 95% ADF. Actual cost estimate for 15 mgd capacity by CH2M Hill, Inc. Cost to rehabilitate line @ \$100/lf, size range is 8" to 24". The operation cost of \$180,000 is based on the additional operation cost projected for upgrade of the existing Wastewater Treatment Plant.

Conclusion

From the graph showing reduction of I&I versus cost, the most economical I&I reduction is 25%. The 25% reduction rehabilitation method is outlined in the SSES report as the recommended rehabilitation method.

The City of Lawton has submitted the SSES Final Report to ODEQ and received authorization to proceed with design and construction. The increased capacity of the existing Wastewater Treatment Plant is scheduled for completion in July of 1999.


COST VERSUS % I & I REDUCTION
COST
$50,000,000
$100,000,000
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% REDUCTION
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